PR

FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by R. W. V. PALMER

VOLUME XXXI: NUMBER 2

UNIVERSITY OF MICHIGAN
NOV 17 1958
FORESTRY LIBRARY

The effect of rate of growth on the density of softwoods
By B. J. RENDLE and E. W. J. PHILLIPS

Tree-crown deformation as an index of exposure intensity
By DAVID THOMAS

The village elms of southern Cambridgeshire
By R. H. RICHENS

Methods of light intensity measurement in forest stands
I. *By* R. D. CONNOR. II. *By* W. A. FAIRBAIRN

The storage of acorns in water
By EUSTACE W. JONES

Moisture and temperature conditions in afforested areas in Aberdeenshire
By J. R. H. COUTTS

The first international symposium on tree physiology
By S. D. RICHARDSON

Oak
By N. WYLIE

Northerwood Conference, 1958
By A. J. GRAYSON

A guide to the named variants of Scots pine
By A. CARLISLE

Published by the
OXFORD UNIVERSITY PRESS
1958

Price Twenty Shillings

SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative in December 1947.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects. It is intended that the Society should be representative of the profession. Those not engaged in the practice of forestry or the allied sciences are cordially invited to join as Ordinary Members.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

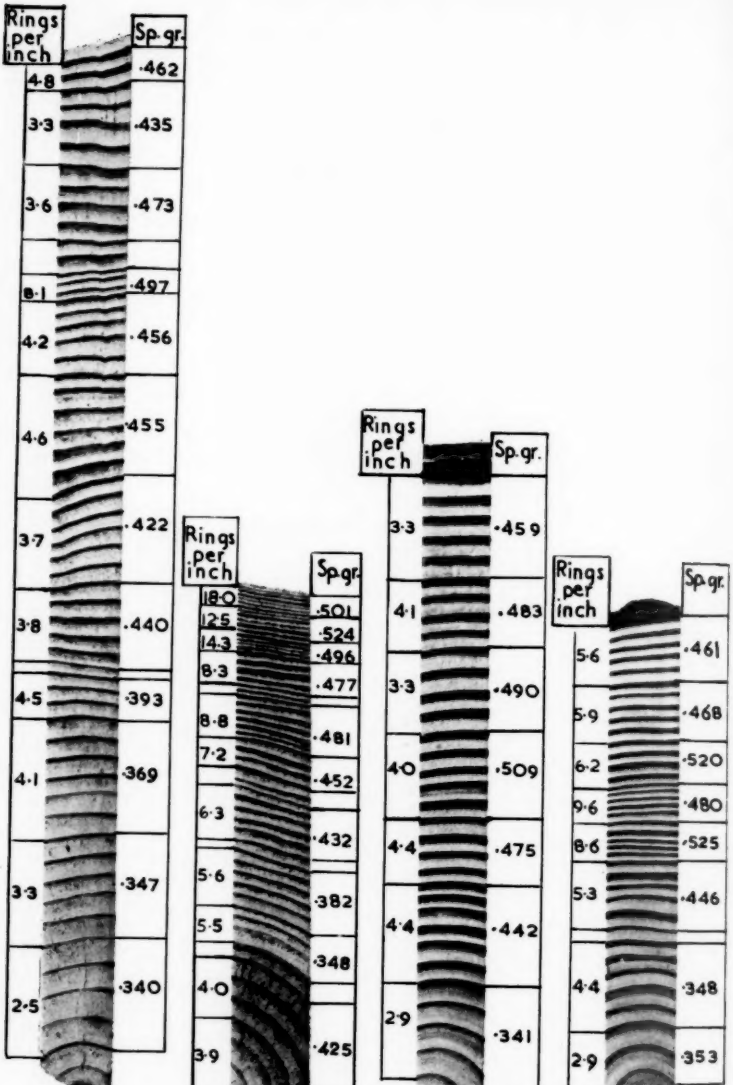
THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year, in May and November. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

CONTRIBUTIONS may be accepted from members and others resident either in Great Britain or abroad. They should be sent to R. W. V. Palmer, Bannerleigh, Leigh Woods, Bristol. No article should be submitted which is being offered to any other journal for prior or simultaneous publication. Plates, figures, and tables should be used sparingly and their proportions designed to suit page dimensions, preferably, but not necessarily, for upright reading. Figures should be drawn large in black ink, preferably on Bristol board, and so as to allow appreciable reduction to page width without loss of clarity in the smaller details. Marginal lettering is best inserted in pencil. If graph coordinates are to be reproduced, graph paper with blue lines must be avoided. References to literature should be collected at the end of the paper, and arranged alphabetically according to author's name, and year published. In the text each reference should be indicated by name, with year in brackets. Each article should begin with a summary which should be factual and convey briefly the content of the article and draw attention to all new information and to the main conclusions. It should be concise and should not normally exceed 200 words. It is understood that the author waives any copyright or translation rights in such summaries and that their reproduction in other publications will be permitted, subject to the source being duly acknowledged. Twenty reprints of the article will be sent free to each contributor and a reasonable number may be purchased by the contributor if ordered when the proofs are returned. The Society as a body takes no responsibility for the views expressed by contributors.

Forestry is sent free to members of the Society; others may register as subscribers by application to the Secretary, The Society of Foresters of Great Britain, 7 Albyn Place, Edinburgh, 2.

SOCIETY'S MEDAL. This may be awarded by the Society to any individual who has rendered eminent services to British forestry. Proposals for the award have to be made in the first instance to the Council by a Member of the Council. The regulations for the award will be found in Vol. XX, pp. 80, 81, and in Rule 11.

[*continued on inside back cover*



Radial variation in density at different rates of growth. The examples are taken from the fastest-grown and slowest-grown trees in the consignments of Corsican pine from Hampshire and Douglas fir from South Devon

PLATE XI

THE EFFECT OF RATE OF GROWTH (RING WIDTH) ON THE DENSITY OF SOFTWOODS*

By B. J. RENDLE and E. W. J. PHILLIPS

(*Forest Products Research Laboratory, Princes Risborough*)

SUMMARY

The relation between rate of growth and density has been examined in fairly wide-ringed Douglas fir (*Pseudotsuga taxifolia*) and Corsican pine (*Pinus nigra* var. *calabrica*) grown in the south of England. A comparison between wood formed early in the life of the tree and wood of similar ring width formed later has shown that the latter is invariably denser, indicating that the higher density of older wood is due to an age effect rather than to diminishing ring width. It is concluded that after a certain age rapid growth can produce wood of reasonably high density. This confirms that Turnbull's findings on widely spaced exotic softwoods grown in South Africa apply, with reservations, to trees grown in this country under conditions where rapid growth can be maintained.

A FEATURE of the Fifth British Empire Forestry Conference in 1947 was Craib's (1947) account of the wide spacing and heavy thinning technique adopted in South Africa and the reports on the quality of the exotic pine timber grown under this system (Turnbull (1947); Scott and Stephens (1947)). Turnbull's work on the timber of *Pinus radiata* (*P. insignis*) and *P. patula* showed that the density of the wood formed in a particular year depends not on the rate of growth (ring width) but on the age of the tree. He found that wood with wide annual rings was as heavy and intrinsically as strong as wood with narrow annual rings of the same age. This conclusion was of special interest to foresters in Great Britain because of the generally accepted idea that wide rings in conifers are associated with low density and correspondingly low strength. This conception was based partly on American and Canadian experience with various softwood timbers and partly on a series of tests carried out at Princes Risborough from about 1929 on home-grown softwoods with the characteristic growth pattern of wide rings in early life and progressively narrower rings later.

The Princes Risborough test results showed a positive correlation between rate of growth (ring width) and the strength and density of the timber, wide annual rings being associated with low strength and density values; but in the light of Turnbull's findings it had to be admitted that the wide-ringed test specimens were mostly from the central core and the narrow-ringed specimens from near the outside of the trees. It would be necessary, therefore, to re-examine the significance of ring width taking ring age into account (Rendle, 1947).

Interest in the effect of rate of growth on the quality of coniferous timber has been revived by recent controversy on thinning practice and notably by Hiley's (1956) insistence that certain schedules which restrict the rate of growth in the later stages of the rotation are uneconomic.

* A revised and extended version of a paper presented to the Seventh British Commonwealth Forestry Conference, 1957.

The general run of home-grown softwood from plantations managed on conventional lines shows a marked decrease in ring width after the early years and is not suitable for studying the effect of ring width on quality at different ages. It is only recently that an opportunity has occurred to examine material from trees in which a rapid rate of growth has been maintained.

To test the validity of earlier conclusions it was decided to make direct comparison in respect of density between wood formed early in the life of the tree and wood of similar ring width formed later. The term 'density' is used for convenience throughout the text in place of the cumbersome 'nominal specific gravity' or ratio: $\frac{\text{weight, oven dry}}{\text{volume, saturated}}$, the quantity actually determined in the investigation. This paper is based on the results so far available.

OBSERVATIONS

The material available was in the form of cross-sectional disks taken from the merchantable bole, in most cases about 20 feet up the stem. A number of radial strips, 1 inch wide and 1½ inches deep along the grain, were cut from these, extending from pith to bark. From each strip blocks for density determinations were carefully dissected with a knife, the aim being to include about five complete rings of similar width in each block. Here and there, a ring which differed appreciably in width from its neighbours was discarded as also were those showing any irregularity such as compression wood.

Two consignments of disks, one taken from six trees of Douglas fir and the other from eight trees of Corsican pine, yielded results of principal interest.

DOUGLAS FIR

The experimental trees, taken from a plantation on deep and fertile clayey loam at North Wood, Dartington, South Devon, were aged 40, 45, and 56 years, two of each being examined. The average spacings ranged from 17 to 22 feet. Comparison of blocks from near the pith with those of similar ring width nearer the bark showed that the outer blocks were denser in each case. Examples from radii in which such direct comparisons were possible are given in Table I (the figures in column 4 may be compared with the corresponding figures in column 8).

The full data, classified according to age and ring width, are plotted in Fig. 1, to show the radial variation in density at each ring width; the density figures represent the mean values for each ring width/age group. The dotted curve, based on the mean density for each age group taking all ring widths together, serves to show the general form of the density variation with distance (in rings) from the pith in the mid-bole timber from these six trees.

The curves demonstrate the marked increase in density which occurred during the first 20 years or so, and the tendency, in this consignment, for density to decrease appreciably beyond about 35 rings from the pith. It was not possible to obtain data for all the ring width classes throughout the whole period of growth covered by the six trees, but the age sequences at each ring width suffice to give a fair idea of the general trends. No significant relationship between ring width and density is evident.

It is of interest to compare the computed average densities of the whole disks cut from the fastest- and slowest-grown trees, namely Tree No. 6 having a volume of 101 hoppus feet over-bark produced in 40 years, and Tree No. 2 with a volume of 52 hoppus feet at 45 years. The average density figures were 0·494 and 0·464

TABLE I. *Comparison of density near the pith and in older rings of similar width. Douglas fir, Dartington, Devon.*

	Wood formed in juvenile period				*Wood formed in later life*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Tree	*Block No.*	*Rings from pith*	*Ring width (in.)*	*Density*	*Block No.*	*Rings from pith*	*Ring width (in.)*	*Density*
1	BN7	9–14	0·15	0·387	BN3	26–28	0·15	0·499
					BN2	29–33	0·15	0·479
	BS6	9–11	0·20	0·371	BS2	28–33	0·18	0·461
					BS1	34–38	0·18	0·420
	BE6	10–14	0·17	0·406	BE1	34–38	0·20	0·460
	BW7	3–5	0·20	0·366	BW2	27–32	0·17	0·489
2	BN7	4–8	0·23	0·348	BN1	34–38	0·18	0·461
	BS6	11–15	0·17	0·410	BS1	34–38	0·16	0·480
	BE5	10–14	0·18	0·395	BE1	33–38	0·16	0·480
3	AW9	8–11	0·20	0·350	AW3	36–40	0·16	0·474
					AW1	46–50	0·16	0·420
5	BN6	3–7	0·23	0·398	BN3	17–21	0·38	0·478
					BN1	28–33	0·27	0·474
	BS6	3–6	0·25	0·387	BS2	23–27	0·29	0·479
					BS1	28–33	0·23	0·459
	BW7	4–6	0·25	0·386	BW4	17–21	0·30	0·474
					BW3	23–24	0·30	0·445
6	BN7	3–6	0·35	0·341	BN3	22–25	0·30	0·490
					BN1	30–34	0·30	0·459
	BS7	3–6	0·33	0·359	BS3	22–25	0·30	0·506
	BE7	4–6	0·37	0·367	BE3	22–25	0·39	0·518
	BW7	3–6	0·30	0·357	BW3	22–25	0·28	0·503

respectively, that is, a volume increase of 94 per cent. is accompanied in this case by an increase of some 6 per cent. in density. Plate XI illustrates the general character of the growth rings in these two trees.

CORSICAN PINE

The observations were made on eight trees mostly from the edge of a plantation established about 65 years ago at Bere Forest in Hampshire. This material is of particular interest since in some of these comparatively old trees diameter growth had been well maintained over a considerable period. The data obtained have been analysed in a similar manner to that described above for Douglas fir. Direct

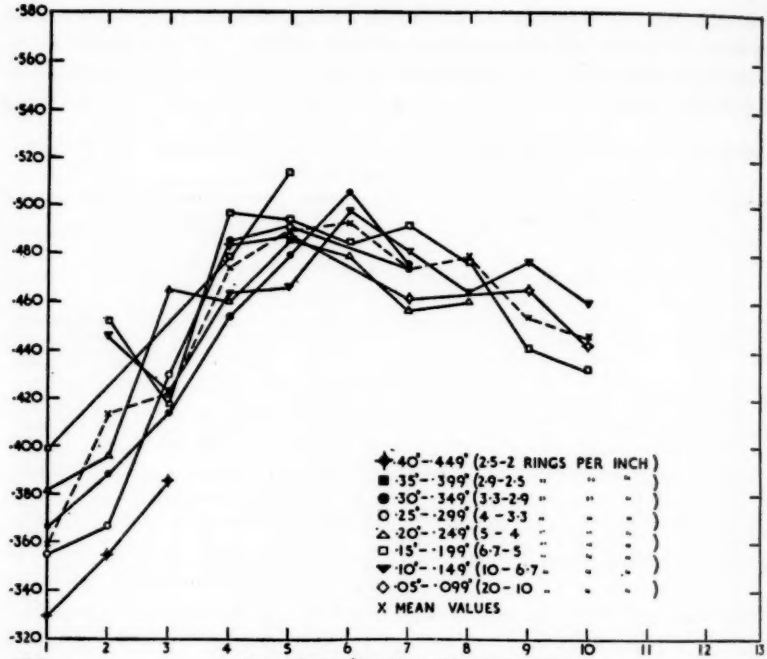


FIG. 1. Douglas fir, Dartington, Devon: relation between ring age and density at constant ring width.

comparison of blocks from near the pith with those of similar ring width at some distance from it again showed the latter to be substantially denser. Examples are shown in Table II. The curves in Fig. 2 differ in certain respects from the corresponding curves for Douglas fir (Fig. 1). The marked increase in density with age is clearly demonstrated, but this approximates more closely to a straight-line relationship than was the case in Douglas fir, with no indication that a maximum density has been attained despite the greater age of the trees. There is, however, an indication that ring width has some relation to density: at a given age, density tends to increase with diminishing ring width.

The computed overall average density of the material from the fastest-grown tree was 0·439 and that from the slowest-grown tree, 0·453. The difference is small, of the order of 3 per cent., corresponding to little more than 1 lb. per cubic foot on the weight of the seasoned timber. Radial strips cut from these two trees are shown in Plate XI.

In addition to these two consignments of Douglas fir and Corsican pine, several specimens of these species from other sources, as well as material of Scots pine, European spruce, and silver fir which have come to hand from time to time have yielded comparable samples having similar ring width at different ages. In all

cases they have shown a marked influence of age on density. Examples are given in Table III (the figures in column 4 may be compared with the corresponding figures in column 8).

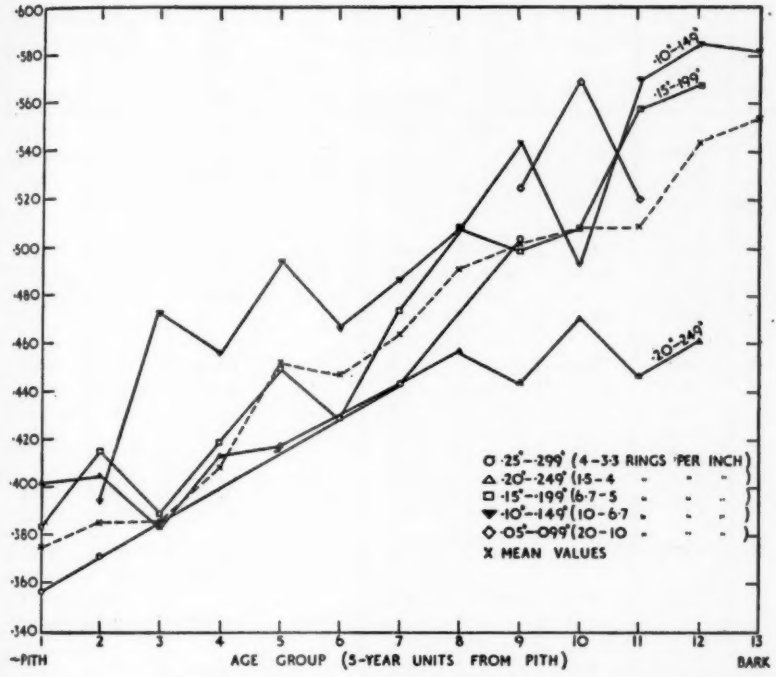


FIG. 2. Corsican pine, Forest of Bere, Hampshire: relation between ring age and density at constant ring width.

CONCLUSIONS

The results of this limited investigation confirm that the density of softwood timber grown in this country varies with the age of the tree; in particular, wide-ringed wood formed in middle life is denser than wood of similar ring width laid down in early life. The higher density of the wood laid down in later years does not depend—as has been assumed—on the falling-off in the rate of growth that generally occurs. This means that after a certain age rapidly grown trees can produce wood of reasonably high density (and strength). It is going too far to assert, as Turnbull has done, that the density of the wood depends almost entirely on the age of the tree when the wood is laid down. This may be broadly true for trees of 30 to 40 years grown under uniform conditions but it is not of general application to softwood grown in the United Kingdom. The data for the Corsican pine from Hampshire (Fig. 2) suggest that ring width influences density independently of ring age, and further investigation on this point is needed; the impression is that

TABLE II. *Comparison of density near the pith and in older rings of similar width. Corsican pine, Forest of Bere, Hampshire.*

	Wood formed in juvenile period				*Wood formed in later life*			
Tree	(1) *Block No.*	(2) *Rings from pith*	(3) *Ring width (in.)*	(4) *Density*	(5) *Block No.*	(6) *Rings from pith*	(7) *Ring width (in.)*	(8) *Density*
1	A1.11	7–10	0·18	0·397	A1.2	59–61	0·14	0·594
	A3.10	9–12	0·20	0·422	A3.5	35–38	0·18	0·521
	A4.12	4–6	0·24	0·389	A4.4	41–45	0·18	0·545
	A4.9	16–20	0·20	0·472				
2	A1.12	4–7	0·23	0·420	A1.5	37–41	0·18	0·557
	A1.10	12–15	0·15	0·423	A1.4	42–45	0·15	0·541
	A2.12	4–7	0·20	0·390	A2.6	39–43	0·15	0·523
	A2.11	12–15	0·15	0·399				
4	1.9	16–20	0·23	0·374	1.4	42–46	0·20	0·444
	3.11	15–18	0·20	0·348	3.4	41–42	0·20	0·431
	4.9	11–14	0·30	0·351	4.2	50–57	0·26	0·440
	A1.10	4–7	0·33	0·339	A1.1	51–55	0·24	0·454
	A1.8	13–17	0·28	0·345				
	A2.7	12–16	0·22	0·341	A2.4	32–35	0·20	0·425
	A3.9	14–16	0·24	0·337	A3.2	48–51	0·23	0·462
5	2.12	6–9	0·20	0·369	2.3	48–50	0·21	0·496
					2.1	55–58	0·20	0·529
	3.9	9–13	0·16	0·369	3.4	37–41	0·16	0·467
					3.1	54–58	0·14	0·529
6	1.11	7–9	0·18	0·374	1.3	39–43	0·17	0·462
	2.8	10–15	0·18	0·358	2.1	48–52	0·17	0·482
	A3.8	7–9	0·19	0·391	A3.1	38–42	0·14	0·476
7	A1.13	5–8	0·15	0·411	A1.1	59–63	0·16	0·554
	A2.11	9–12	0·13	0·389	A2.4	43–47	0·13	0·576
					A2.1	58–62	0·15	0·558
	A3.14	4–7	0·17	0·376	A3.4	47–49	0·18	0·532
8	A1.11	8–12	0·30	0·347	A1.2	54–57	0·30	0·435

fast-growing trees tend to produce lighter wood than slow-growing ones, age for age, but it is clear that the importance of ring width in determining the density (and strength) of softwood has been overrated. In particular the idea that wide-ringed softwood is necessarily weak is erroneous and where the forester's object is to produce general utility timber there appears to be no point in restricting the rate of diameter growth on good sites where a rapid rate (say, 4 rings per inch) can be maintained, provided the timber so formed is not unduly knotty.

Observations made so far indicate that the change-over from low-density

'juvenile' wood to wood of 'adult' density is related to distance from the pith as counted in rings rather than as measured in inches. This means that a stem which grows rapidly in the early years will, as a rule, have a larger core of low-density wood than a tree of slower initial growth, although the actual densities of the two cores may not be very different. It follows that a tree grown rapidly at the start must be allowed to grow to a substantial diameter if it is to make a worthwhile

TABLE III. *Comparison of density near the pith and in older rings of similar width: further examples*

	Wood formed in juvenile period				*Wood formed in later life*			
Material	(1) *Specimen No.*	(2) *Rings from pith*	(3) *Ring width (in.)*	(4) *Density*	(5) *Specimen No.*	(6) *Rings from pith*	(7) *Ring width (in.)*	(8) *Density*
Silver fir (*Abies alba*), Consignment 643, Yugoslavia	A1	2–10	0·13	0·335	A5	47–57	0·07	0·400
	A2	7–20	0·09	0·335				
European spruce (*Picea abies*), Consignment 643, Yugoslavia	C1	3–18	0·11	0·313	C5	48–56	0·10	0·400
Scots pine (*Pinus sylvestris*), Consignment 869, New Forest, Hampshire	S3/1/10	11–15	0·09	0·430	S3/1/4	50–55	0·07	0·508
	S3/1/7	23–29	0·07	0·465				
Corsican pine (*Pinus nigra* var. *calabrica*), Thetford, Norfolk	C3/S5	8–12	0·10	0·395	C3/S/1	33–38	0·09	0·495
	C3/S4	13–17	0·07	0·450				
Douglas fir (*Pseudotsuga taxifolia*), Abbotswood, Forest of Dean, Glos.	D2/W4	13–17	0·08	0·435	D2/W1	22–27	0·08	0·471
	D3/W5	8–12	0·28	0·347	D3/W2	23–27	0·26	0·389

layer of the denser wood. Once the adult condition is reached the larger diameter tree can, of course, then more quickly produce a large volume of the denser wood even at a moderate rate of growth as measured in rings per inch.

As regards the anatomical basis for variation in density, it has been shown that, during the early life of the tree, the thickness of the summerwood cell walls (and hence the density of the summerwood) and also the percentage of summerwood

tend to increase with age (Larson, 1957). This can in fact be seen in the photographs of Corsican pine and Douglas fir in Plate XI. A complicating factor opposing this trend of increasing density is the gradual increase in the overall size of the cells during the juvenile period, which tends to reduce the density of the wood (Jones, 1958). Thus it is probably the small diameter of the cells in the innermost rings that accounts for the density being sometimes high near the pith (where the cells are smallest) and then showing a fall for a few years before rising to the higher values associated with the adult condition; see, for example, Phillips's (1941) and Bryan and Pearson's (1955) graphs for Sitka spruce grown in Great Britain. Thus comparisons of density between inner and outer rings within the juvenile zone may not accord with those made between juvenile and fully adult wood.

It is pertinent here to stress that in investigations of this kind care should be taken to avoid certain features which may mask any basic relationship between density and ring age. These features include compression wood (which may be very much heavier than normal wood and may occur at any age but is particularly common in young stems), heavy deposits of resin associated with heartwood formation or with wounds, and wood in the vicinity of knots.

It is desirable to investigate further the technical properties of wide-ringed softwood and the implications of wider spacing and heavier thinning. Much remains to be learned also about the influence of environmental and other factors on the structure and quality of the wood laid down at different periods in the life of a tree. These factors must be borne in mind when considering how fast it is safe to grow each species and yet obtain timber of acceptable quality.

ACKNOWLEDGEMENTS

The investigation described above was carried out as part of the programme of the Forest Products Research Board and is published by permission of the Department of Scientific and Industrial Research. Thanks are due to Mr. W. E. Hiley, Chairman of Dartington Woodlands Ltd., and Dr. F. C. Hummel, Forestry Commission, for their co-operation in locating and providing the bulk of the material used in the investigation.

LITERATURE REFERENCES

Bryan, J., and Pearson, F. G. O. (1955): 'The Quality of Sitka Spruce Grown in Great Britain.' *Empire Forestry Review*, xxxiv, 2, 1–16.

Craib, I. J. (1947): 'The Silviculture of Exotic Conifers in South Africa.' *Fifth Br. Emp. For. Con.*

Hiley, W. E. (1956): *Economics of Plantations*. Faber & Faber Ltd., London.

Jones, G. B. (1958): 'Variations in Cell Size and Cell Wall Thickness in Norway Spruce, *Picea abies* Karst.' *J. Oxford Univ. Forest. Soc.* 4th Series, No. 5, 35–43.

Larson, P. R. (1957): 'Effect of Environment on the Percentage of Summerwood and Specific Gravity of Slash Pine.' *Yale University, School of Forestry Bull.* No. 63. New Haven.

Phillips, E. W. J. (1941): *The Relation of Anatomical Structure to Compression Strength in Homegrown Sitka Spruce*. Forest Products Research Laboratory, Princes Risborough, Project 18, Progress Report 6.

Rendle, B. J. (1947): *Fifth Br. Emp. Con., Great Britain. Proceedings*, p. 200.

Scott, M. H., and Stephens, R. P. (1947): 'The Quality of Mature *Pinus patula* and *P. insignis* Timber Grown in South Africa.' *Fifth Br. Emp. For. Con.*

Turnbull, J. M. (1947): 'Some Factors affecting Wood Density in Pine Stems.' *Fifth Br. Emp. For. Con.*

TREE-CROWN DEFORMATION AS AN INDEX OF EXPOSURE INTENSITY

By DAVID THOMAS

(Department of Animal Husbandry, University College of Wales, now with Department of Geography, University College, London)

SUMMARY

The paper opens with a short critical review of the literature available notably from Japan, Germany, and the United States and then, as a result of a pilot investigation in north Cardiganshire, proposes five tree-deformation classes suitable for the differentiation of various degrees of exposure in agricultural areas in the British Isles. A primary aim of this classification is to standardize types and eliminate subjective elements in the recording of field observations. To illustrate this classification the detailed survey carried out in the Melindwr valley using hawthorn (*Crataegus* spp.) as the indicator is discussed and illustrated by two maps which show both the direction and the degree of deformation in the valley. The paper concludes that whilst absolute wind-speed values cannot be assigned to deformation types, important exposure differences not associated with catastrophic events, can be distinguished over small areas with sufficient accuracy to give a basis for the classification of shelter needs.

THE asymmetrical form imposed upon tree crowns as a result of the effects of wind blast has long been a topic which has engaged attention. In 1814 Davies dealt at length with such phenomena on exposed and coastal sites in South Wales (Davies, 1814), whilst later workers, such as Stamp (1948), have stressed the importance of the characteristically distorted tree shapes, as a reflection of wind conditions, not only in coastal areas but also on elevated inland locations. Similar interest has been aroused abroad, notably in Japan, Germany, and the United States. The purpose of this paper is, firstly, to provide a critical review of the work already published on this topic, some of which is not readily accessible, and, secondly, to suggest, by utilizing the results of a pilot survey over a small part of Cardiganshire, a means by which the effective exposure, and hence possible need for agricultural shelter, in any area may be assessed by a study of the wind distortion of trees.

A REVIEW OF PUBLISHED MATERIAL

The work carried out by H. and K. Misawa (1954) in the Nagano Prefecture of central Japan was concerned mainly with the study of the wind distortion of persimmon trees. By the use of this index they were able to show not only the indicated general wind trends over the whole of the Prefecture, but also the extent to which local topographic features exerted an influence upon the general air flow. In the vicinity of meteorological stations a close correlation was observed between the direction of winds inferred from the persimmon tree deformation and that actually recorded instrumentally for the summer months. The suggestion was made that the prevailing winds in autumn and winter could similarly be inferred from the wind distortion of rice plants and reeds, respectively.

In a rather more detailed way Sekiguti (1951) also studied the deformation of persimmon trees in the Nagano Prefecture. Having established, by general observation, a close association between the prevailing wind indicated by the crowns of persimmon trees and that by a local meteorological station, he set out, by comparing the records of twenty-two independent observers, to assess the human error involved in the estimation of the direction of deformation. From a statistical examination of the results, Sekiguti estimated a maximum error of $\pm 15°$.

The results of the observations of Sekiguti and his associates of tree deformation in the Akaho Fan region were depicted on a large-scale map. The consequent pattern was then verified by actual measurements of wind speed and direction at various points in the area when the wind direction, on exposed sites, was that indicated by tree distortion. Apart from establishing that persimmon trees served as reasonably accurate indicators of air movement, Sekiguti was also able to illustrate the effects of topographic features upon wind force and direction. The windward shelter provided by a steep escarpment bordering the Fan was shown, together with the modifications to the general air flow caused by deep transverse river valleys which dissected the Fan surface. A distinction was made between the smaller valleys, in which the wind was canalized in the direction of the stream, and the wider valleys where greater turbulence led, in some cases, to a complete reversal in the direction of the distortion of tree crowns. Thus the Japanese work showed that, providing a sensitive indicator is used, tree deformation represents a long-term adjustment to the dominant wind direction, which is frequently closely related to local topographic configuration.

Weischet (1953), in his review of German work on the subject, suggests that the calibration of the extent of deformation is possible. He stresses the point, however, that different trees react very differently to any given wind speed, which makes it extremely difficult to devise a deformation scale. He was able, nevertheless, as a result of his investigation to the north of the Eifel, to rank a number of species in order of increasing power of resistance to wind and also to distinguish two types of deformation, namely 'incipient' and 'complete'. The first was applicable where the outermost twigs and shoots were diverted from their normal direction of growth, and the second referred to total deformation, where the boughs were bent or killed. To each of these deformation types in a number of species Weischet assigned windiness grades, the basis of which is not made clear. The four grades, however, do appear to represent wind strengths increasing from 'grade 1' to 'grade 4'. The results of his work are shown in Table I, where the various wind grades which impose 'incipient' or 'complete' deformation are shown against the appropriate species.

In his report on the Smith–Putnam wind-turbine project in central Vermont, U.S.A., Putnam (1948) summarized the results derived from the special wind-research programme which had been carried on from 1940 to 1945 in order to analyse the wind behaviour in the mountains of New England. A major element in this investigation was an attempt to correlate the observations of the different kinds of tree deformation with actual wind conditions indicated by anemometer records. It is interesting to note that many of the findings in the ecological aspects

of this work are corroborated by the research of Golding (1955) in this country, who was also concerned with the generation of electricity by wind power.

The physiological basis of tree deformation by wind was examined by Putnam as far as present knowledge then allowed. His conclusion, that although trees may be broken by isolated violent storms, they owe their distorted shapes to habitual rather than exceptional wind conditions, confirms the basic assumptions made by the German and Japanese workers that trees record long-term wind effects. His

TABLE I. *Wind strengths which induce deformation in various species (after Weischet)*

Deformation types	*Sweet cherry, pine*	*Mountain ash*	*Silver poplar, apple, pear*	*Beech*	*Horse chestnut*
Incipient . .	1	2	2–3	3	4
Complete . .	1–2	2–3	3	4	

warning also against the possible confusion with distortion due to causes other than wind, principally salt damage, is worthy of note, especially in view of Edlin's recent discussion of the effects of salt blast in the browning and defoliation of trees in south-east England (Edlin, 1957).

As a result of the wind-research programme, Putnam distinguished five types of wind deformation in trees using the balsam (*Abies balsamea*) as his principal indicator. The smallest detectable distortion in the topmost twigs was described as 'brushing'. 'Flagging' was said to occur when the tree branches stretched to leeward whilst the trunk was left bare on the windward side. When the main trunk of the tree, as well as its branches, was deformed and leaned away from the prevailing wind, 'throwing' was said to have occurred. 'Wind clipping' described a situation in which the wind had been sufficiently severe to suppress the leaders and hold the tree tops to a common, abnormally low level, whilst the most severe wind conditions were reflected by the development of 'tree carpets', where upright growth was inhibited and a carpet of prostrate branches spread over the ground.

Thus, although Putnam recognized that there were considerable periods of the year in which wind conditions did not lead to deformation, for example, the times of occasional violent storms or the far longer periods of breezes too light to affect normal tree growth, he was able to show a very close correlation between his deformation types and the instrumentally recorded mean annual wind velocity. Table II, abstracted from his data, shows the wind-speed values at which the various types of deformation in conifers were detected.

Hence, in the first place, distorted trees give an indication of the direction of the damaging wind. The effect of the wind is clearly most potent at the time when the tree is putting out new shoots and leaders and thus the emphasis amongst workers in Japan, where there exists a well-marked monsoonal dualism in wind régime, has been upon the seasonal nature of the winds in spring and early summer. Putnam's attention, on the other hand, was directed towards coniferous

species, and he consequently lays emphasis upon their response to wind conditions throughout the year. However, from an agricultural point of view, an assessment of the relative exposure to which both animals and crops are subject has greatest point over the early part of the year, the very period when deciduous trees are most susceptible. Secondly, there is obviously a relationship between the extent of distortion and the severity of wind conditions, although, of course, the

TABLE II. *Mean annual wind speeds which induce deformation in conifers (after Putnam)*

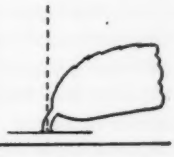
Specimen height above sea level (feet)	*Types of deformation of conifers*	*Mean annual wind velocity (V) at height of top of specimen above ground (x feet)* V_x *m.p.h.*
4,100	Balsam, spruce, and fir held to 1 foot	$V_1 = 27{\cdot}0 \pm 1{\cdot}0$
4,040	Balsam, spruce, and fir held to 4 feet	$V_4 = 21{\cdot}5$
4,100	Balsam thrown	$V_{25} = 19{\cdot}2$
3,900	Balsam strongly flagged	$V_{30} = 18{\cdot}6$
4,000	Balsam flagged	$V_{30} = 17{\cdot}9$
3,700	Balsam shows minimal flagging	$V_{40} = 17{\cdot}3$
2,560	Balsam unflagged	$V_{40} = 15{\cdot}5$
1,400	Hemlock and white pine show minimal flagging	$V_{40} = 10{\cdot}6$

manifestation of the relationship will vary from species to species. Whether, however, the association can be expressed in terms of absolute wind speeds, as Putnam attempted to do, is open to debate, but there can be little doubt of the validity of his classification as a comparative measure of wind conditions. Thirdly, there emerge the advantages in detailed work, which arise out of the use of tree deformation as an indicator of air flow in relation to comparatively minor topographic variations, and lastly, some of the limitations of the technique are clearly indicated. Not only has the error in assessing tree distortion to be borne in mind, but also distortion due to factors other than wind has continually to be guarded against in order to avoid faulty interpretation.

FIELD INVESTIGATION

Preliminary surveys of exposed areas in north Cardiganshire brought to light certain practical considerations which have a bearing upon the determination of tree distortion. The laying and trimming of hedgerows affects considerably the orientation of the branches within them, making the study of hedge timber itself inadmissible. Records of deformation must thus be derived from tree timber which exists independently of hedgerows or which stands within, but above the normal hedgerow level and is not subject to periodic cutting or trimming. The excessive distortion imposed upon tree crowns in severely coastal areas, as a result of salt damage, became immediately obvious, but until more is known of the effects of atmospheric salinity upon vegetation, these areas must be excluded. Also, special vigilance is needed to detect distortion due to other causes. For

TABLE III. *Tree deformation classification*

Deformation class	*Extent of deformation in trees*	*Pictorial representation of tree profile*
I	No detectable distortion.	
II	'Brushing'—topmost twigs and branches deformed, but no general asymmetry imposed on crown.	
III	Asymmetrical crown, but less than ⅓ of branches and foliage to leeward of perpendicular line from the point where the centre of the trunk enters the ground.	
IV	More than ⅓ of branches and foliage to leeward of perpendicular line from point where the centre of the trunk enters the ground, but not whole crown.	
V	'Throwing'—whole of crown to leeward of perpendicular line from point where the centre of the trunk enters the ground.	

example, the growth of two trees in close proximity to one another results in each having a distorted crown; the felling and removal of one tree can then lead to a possible misinterpretation. Again, the disturbance of the whole trunk of a tree

in the soil as a result of a severe gale, soil creep, or undermining on a stream bank is not an uncommon feature.

The extent to which any given mean wind force will distort a tree will depend upon a number of factors. The species of the tree is obviously very important. Any classification of distortion should thus be limited to a few species, such as hawthorn, oak, or mountain ash, which have a reasonably dense and random distribution throughout the country. Although Putnam favoured conifers, they seem of little value in this country as indices of exposure on a field-to-field scale because they frequently occur only in extensive stands, which themselves modify considerably the general air flow (Geiger, 1950). The age of a tree and also its height above ground level are other factors which affect the extent of its distortion. In practice, however, these last points seem of less importance than the effects of micro-topographic shelter, which may allow trees to begin their growth unaffected by wind blast only to be distorted as they grow upwards into unsheltered air.

From field studies it was found that a more refined classification than that outlined by Putnam was necessary in differentiating various degrees of exposure in agricultural areas in this country. Whilst 'wind clipping' and 'tree carpets' occur, greater selectivity was needed in defining tree distortions which indicate the less severe, and agriculturally more marginal wind conditions, as shelter need in areas where trees are damaged excessively by wind may be taken for granted. Again, deciduous species which met the distribution requirements above were found not to assume the same well-defined shapes as the balsam trees observed by Putnam and his collaborators. Hence Table III shows the classification found most suitable in the definition of exposure zones in north Cardiganshire for the purpose of assessing relative exposure intensity. One of the principal aims has been to standardize the recognition of deformation types in order to eliminate, as far as possible, any subjective elements in the recording of field observations.

FIELD METHOD

As an illustration of the application of the above classification, a detailed field survey was carried out in the Melindwr valley, near the village of Goginan, Cardiganshire (Nat. Grid. Ref. SN/6881), where the ubiquitous hawthorn tree was used as an exposure indicator. In terms of Weischet's classification (Table I) the hawthorn emerges as an extremely sensitive tree, for it was observed to suffer greater deformation than the mountain ash, when the two trees were similarly sited and closely juxtaposed. The area was chosen not only because it was sufficiently far from the sea to obviate the effects of salt damage but also because the orientation and physiographic form of the valley promised interesting relationships between topography and exposure. The methods involved in producing Figs. 1 and 2 are discussed in order that a better estimate may be made of the significance of the findings.

Field notes were made of the following features for each tree examined; the species, the line of direction of maximum distortion, the deformation classification, and the height of the lowest noticeable traces of distortion, estimated as the perpendicular distance from the point at which the trunk entered the ground.

The line of direction of maximum distortion was obtained by viewing the tree from the point where distortion appeared to be at a maximum. A bearing was then taken by prismatic compass from this point to the centre of the canopy. An angle of 90° was either subtracted from or added to this bearing to obtain the line of direction of maximum distortion. The position of observation was then changed so that the bearing indicated by the prismatic compass was that normal to the first sight. If this appeared to be a fair estimate of the line of direction of maximum distortion (i.e. point from which distortion was at a minimum), then the original calculation was verified and accepted. The point from which distortion was at a maximum was used as a basis for measurement in preference to that from which distortion was at a minimum, because it was found to be far easier to fix with accuracy. The deformation class could also be determined at the same time from this point. The height of the lowest deformation was noted as a guide to areas of shelter provided by limited topographic features.

The procedure for each tree was carried out by two different observers working independently. In an attempt to minimize the human errors involved in noting observed phenomena, the value used for the bearing of the direction of distortion was the mean of the two recorded bearings. Similarly, when the two deformation classifications for the same tree differed, the distortion was considered to be borderline in character.

DISCUSSION OF RESULTS

From the observed direction of hawthorn deformation upon the last inland vestige of the 600-foot Coastal Plateau (Brown, 1950) to the north-west of the area shown on Fig. 1, and also upon sites of all-round exposure to the south-east of Goginan, it may be inferred that the dominant free-wind direction is west-south-west. However, the modification which the Melindwr and its tributary valleys imposed upon this general air flow is marked. Thus to the south-west of the area the funnelling of wind through the narrow entrance to the valley has given a south-westerly trend to the deformed trees, whilst to the east of Goginan and especially in the Nant yr Arian and Nant Brwyno valleys a reorientation of almost 90° to north-west has taken place. Wind deflexion by less-pronounced features is also indicated on the spur to the south-east of Goginan and on the hill to the north-east of that village.

The intensity of exposure, defined by hawthorn deformation (Fig. 2), is in many ways related to this pattern. Whilst it might be expected that the majority of the areas at or over 600 feet, open to the winds blowing unhindered across the flat areas and concordant summit levels of the Coastal Plateau, would experience severely exposed conditions and the valley floor remain well sheltered, there are many anomalies resulting from the orientation of the wind blast due to topographic configuration. Thus, the narrow-necked entrance to the valley in the south-west of the area, although below 200 feet, experiences Class III deformation due to the canalization of wind, whilst the south-west edge of the erosion remnant facing this narrow passage is also severely blasted. Similarly, other natural obstructions impeding air flow along the valley floor experience exposed conditions.

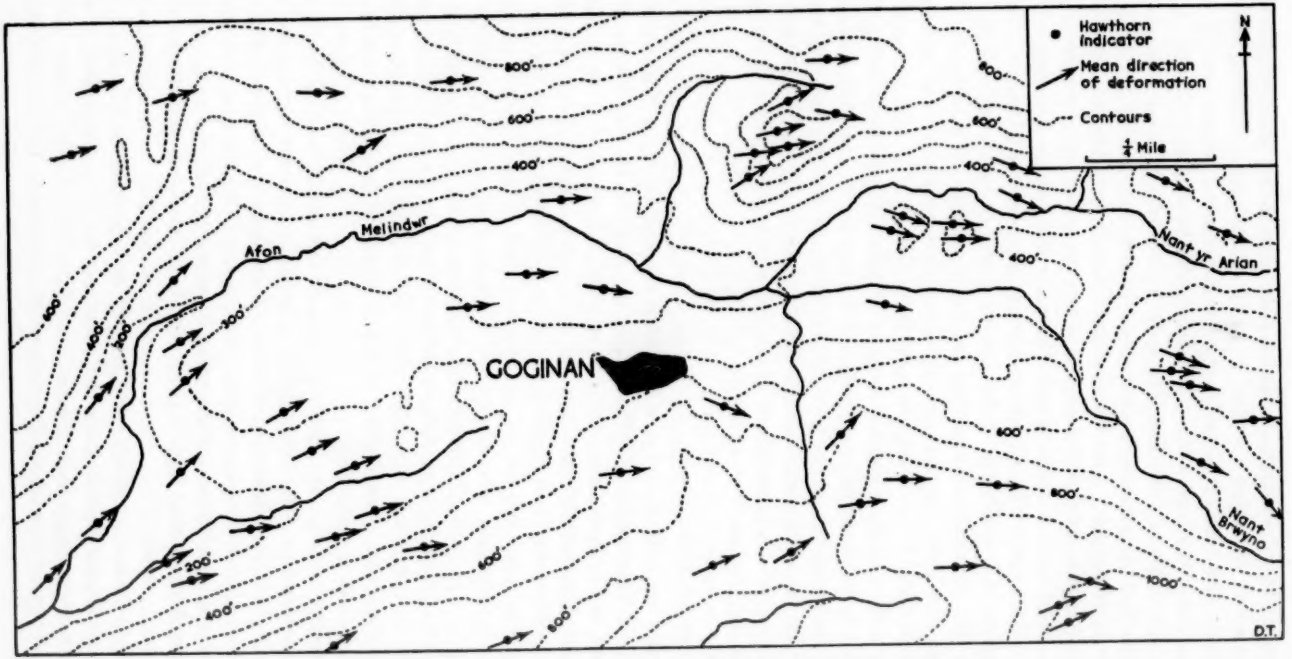


FIG. 1. The direction of Hawthorn Deformation in the Melindwr Valley, Cardiganshire

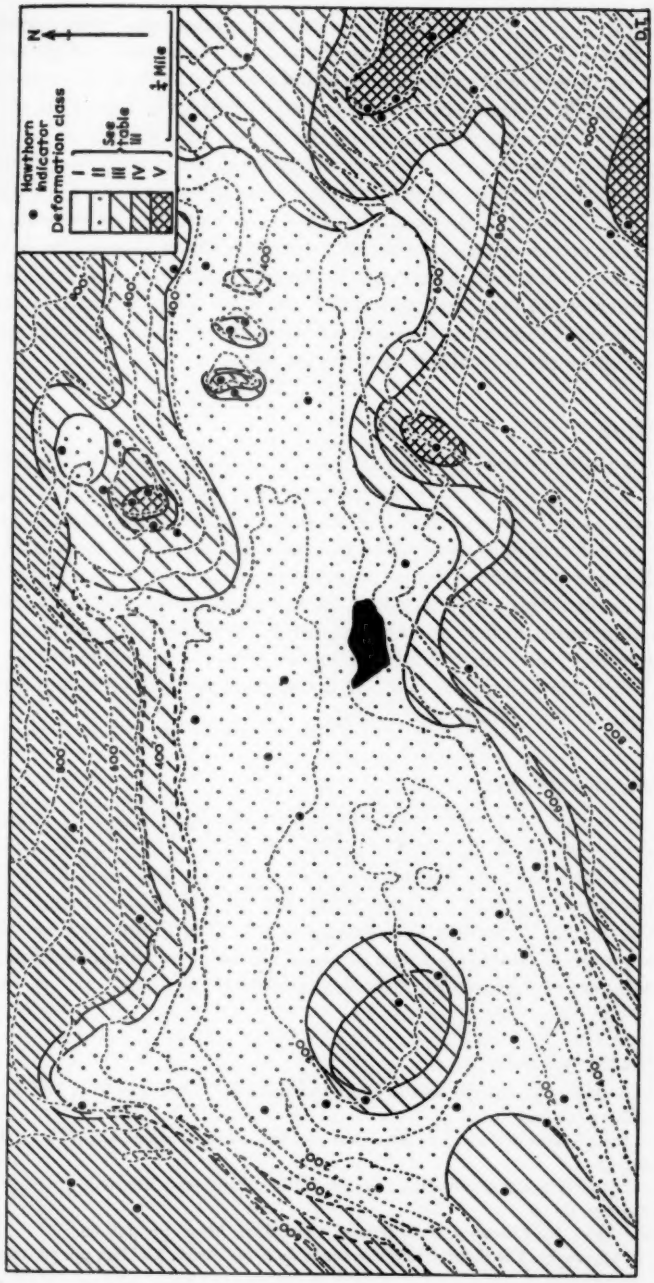


FIG. 2. Exposure zones, defined by Hawthorn Deformation, in the Melindwr Valley, Cardiganshire

Three hillocks at just over 400 feet to the east of Goginan are clearly affected in this way, together with the out-jutting spur to the south-east, and the conical hill to the north-east of the village, both at over 700 feet. The north-west-facing slope of the spur between the Nant yr Arian and Nant Brwyno valleys also receives the full force of the wind sweeping along the major valley floor.

Appreciably sheltered areas similarly emerge from the distribution shown on Fig. 2. The north-west and south-east-facing valley sides to the west of Goginan, where in places Class II deformation occurs at 700 feet, may be included here. However, the extensive tree plantations upon these slopes have made the exact definition of exposure-zone boundaries impossible. Hence a broken line has been used to differentiate exposure types which are more hypothetical than actual. Again, topographic shelter is provided by the spur on which Goginan itself is built and also by the conical hill to the north-east.

CONCLUSION

Thus, by the study of tree deformation, a technique has emerged whereby the prevalent direction and relative intensity of wind blast may be determined in agricultural areas in this country. Whilst absolute wind-speed values cannot be assigned to deformation types, significant exposure differences over small areas can be distinguished with sufficient accuracy to give a basis for the classification of shelter needs within a specified area. As severe conditions not associated with the prevailing quadrant may occur during critical periods in the life-cycle of either plants or animals, it is equally clear that a more refined technique must be applied to detect and define situations in which artificial shelter may be required as protection against these catastrophic events.

ACKNOWLEDGEMENTS

The above work has formed part of the Livestock Shelter Research Programme being carried out at the University College of Wales, Aberystwyth, under the direction of Professor J. E. Nichols, to whom thanks are due. Valuable assistance and advice was also given by Messrs. R. W. Gloyne and W. H. Hogg (Meteorological Office) and Messrs. M. W. Edwards and R. Lines (Forestry Commission), to whom grateful acknowledgement is made. The work was supported financially by the Ministry of Agriculture, Fisheries, and Food.

LITERATURE REFERENCES

Brown, E. H. (1950): 'Erosion Surfaces in North Cardiganshire.' *Trans. Pap. Inst. Brit. Geogr.* 16, London, pp. 51–66.

Davies, W. (1814): *General View of the Agriculture and Domestic Economy of South Wales*, I, London, pp. 263–9.

Edlin, H. L. (1957): 'Saltburn following a Summer Gale in South-east England.' *Quart. J. For.* li, London, pp. 46–50.

Geiger, R. (1950): *The Climate near the Ground*, Cambridge, Mass., pp. 336–66.

Golding, E. W. (1955): *The Generation of Electricity by Wind Power*, London, pp. 70, 169, 170.

Misawa, H., and Misawa, K. (1954): 'On some Phytometers of Seasonal Winds.' *J. Agric. Met.* 9, Tokyo, pp. 77, 78.

Putnam, P. C. (1948): *Power from the Wind*, New York, pp. 51–60, 82–87.

Sekiguti, T. (1951): 'Studies on Local Climatology (III); On the prevailing Wind . . . .' *Papers in Met. and Geophys.* ii, Tokyo, pp. 168–79.

Stamp, L. D. (1948): *The Land of Britain, its Use and Misuse*, London, p. 262.

Weischet, W. (1953): 'Zur systematischen Beobachtung von Baumkronendeformationen mit klimatologischer Zielsetzung.' *Met. Rund.* 6, Bad Kissingen, pp. 185–7.

FORESTRY POLICY FOR THE UNITED KINGDOM

The End of an Epoch

A STATEMENT about forestry policy was made in the House of Commons on 24 July 1958 by the Minister of Agriculture, Fisheries, and Food, Mr. John Hare. The Minister said that in accordance with the announcement made in October 1957, forestry policy had been reviewed by the Government and the details now given by him were the conclusions reached by the Government in the light of current conditions—strategic; economic; agricultural; and social. The Government recognized the importance of the forestry industry and of an efficient home-grown timber trade and believed the measures now announced would be welcomed by the trade as well as by woodland owners and would help both to plan ahead with confidence.

The details given in the statement will be well known and will have been subjected to critical examination long before they can be read in this Journal. In brief, they assure more confidence by settling the extent of the planting programme ahead for ten years with subsequent five-year revisions in the light of 'national needs'. They insist that special attention be paid to the upland areas, particularly in Scotland and Wales. Support is to continue to private woodland owners, particularly through the dedication scheme. There is to be a new structure of grants contingent upon the formation of an effective woodland owners' association as recommended by the Watson report and these grants are to be reviewed at intervals of five years in the light not only of trends in costs but also of trends in receipts from private woodlands as a whole, visualizing optimistically reduction with rising income in twenty to thirty years time to a nominal amount. Felling licences are to continue with relaxations, but 'in the present circumstances it does not seem necessary to continue to fix a quota for the total annual felling'.

It is suggested that the last sentence is the most significant. The abolition of the quota means the end of an epoch. The end of a forty-year struggle during which planting and the conservation of existing stocks against blockade in war have been the paramount needs. The way is now open for proper planning for management and for the marketing and processing of the produce of an assured forest estate of known size, partly state and partly private, on sound economic and profitable lines.

STUDIES ON *ULMUS*

II. *The Village Elms of Southern Cambridgeshire*

By R. H. RICHENS

(*Commonwealth Bureau of Plant Breeding and Genetics, Cambridge*)

SUMMARY

In continuation of a preliminary study on the range of variation of East Anglian elms (*Watsonia*, iii (1955), a taxonomic survey was made of the village elms of southern Cambridgeshire. The number of samples collected was 132. For each of these, 8 quantitative and 1 qualitative character were measured. The samples could be classified into 7 biometrically defined groups, 6 pertaining to *U. carpinifolia* and 1 to *U. procera*. The two species are linked by intermediate forms.

At least two introductions of *U. carpinifolia* into Cambridgeshire seem to have occurred, one of which appears to have been no later than Roman. *U. procera* was introduced no later than in the Middle Ages.

IN the first paper of this series (Richens, 1955), a preliminary survey was made of the range of variation of elms in major square 52 of the Ordnance Survey national grid. The object of the present paper is to present the results of a more intensive survey of a smaller area, analysing eight instead of five quantitative leaf characters as previously. In the earlier paper, some hypotheses on the history of the elm in East Anglia were considered. Further evidence on this topic is discussed below.

SAMPLING TECHNIQUE

The area surveyed was the county of Cambridgeshire, as constituted before the boundary changes of 1895–6 and excluding the Isle of Ely. Within this area several distinct regions can be distinguished. Running from north-east to south-west across the county is an outcrop of chalk along which runs the prehistoric Icknield Way. To the south and east of this outcrop is a region of highish land in which boulder clay covers the underlying chalk. The soil to the north and west of the chalk outcrop is mainly clay, either gault or boulder clay; to the west of the county the boulder clay extends over a well-marked plateau. Fen deposits occur in the extreme north of the area and along the Cam.

Most of the county is in the basin of the Cam. For convenience, the river to the north of Cambridge will be called the Lower Cam; the three principal branches of the Upper Cam south of Cambridge will be termed the Western, Southern, and Eastern Cam, respectively. The Bourn Brook runs into the Cam from the west, to the north of the Western Cam. The Ouse bounds our area to the north.

From the facts considered in the earlier paper, it appeared that all the East Anglian elms except *U. glabra* Huds. were probably of human introduction; it was therefore decided to sample from the ancient pre-enclosure closes around the settlements of each parish rather than from the boundary hedges as in the first

paper. Usually a single tree from each parish was sampled unless markedly dissimilar trees were noted, in which case each divergent type was sampled. In some cases where two or more parishes constitute a single settlement, as is fairly frequent in Cambridgeshire, or where two originally distinct parishes have been consolidated and the boundaries are no longer known, the combined settlement has been treated as a single sampling unit.

BIOMETRIC TECHNIQUE

Eight quantitative foliar characters were measured: absolute length of the longer side of the lamina; lamina breadth / lamina length; petiole length / lamina length; the degree of basal asymmetry; the number of teeth; and the breadth, length, and depth of the primary teeth. The tendency towards obverse configuration was not measured since the earlier survey showed that this character varied much more within a single tree than the other characters. The other measurements were made as before with the addition of lamina length and three measurements

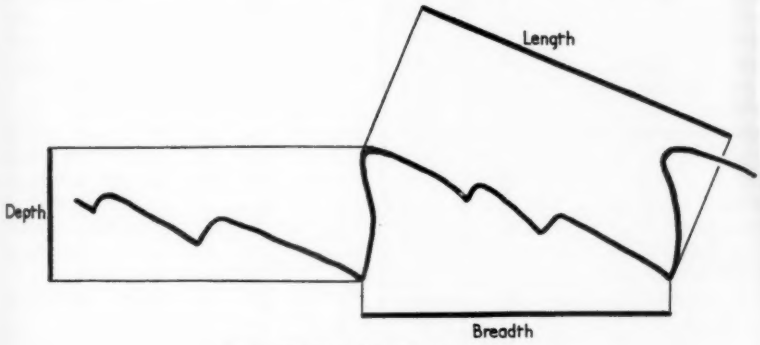


FIG. 1. Diagram of tooth measurements.

of individual primary teeth. For these, a typical primary tooth in the subapical region of the longer side of the leaf was chosen at random for each leaf. By primary tooth is meant the major unit of dentation, which almost always carries secondary teeth in this portion of the leaf. A secondary vein normally runs into the apex of each primary tooth. The measurements made (to the nearest 0·5 mm.) can be seen from Fig. 1. As before, it was noted whether the leaves were smooth or scabrous. The latter are denoted by an asterisk; leaves not indicated so are smooth.

Five leaves per tree were measured and means for each character were calculated, together with the range. In the earlier paper, tests for significance of the difference between means were made by the t test. This was too laborious for the amount of data studied in the present paper. As an alternative, the approximate G test based on range (Jackson and Ross, 1955) was used. Each tree was compared in this way, in respect of each of the eight quantitative characters, with all other sampled trees; a record was made of all pairs of samples that did not differ significantly at the $P = 0{\cdot}05$ level in each of the eight quantitative characters.

TABLE I. *Mean scaled values for (1) length, (2) relative breadth, (3) relative petiole length, (4) basal asymmetry, (5) tooth number, (6) tooth breadth, (7) tooth length, and (8) tooth depth. Grid reference is to minor squares of major square 52.* *scabrous

Parish		Grid reference	Biometrical values
Abington Piggots		34	5 . 2 5 2 . 4 . 3 4 4
Arrington		35	4 . 5 8 3 . 4 . 3 4 5
Ashley		66	5 . 4 4 4 . 2 . 6 7 6
Babraham		55	5 . 4 5 6 . 2 . 7 8 7
Balsham		55	4 . 6 7 5 . 2 . 7 7 6
Barrington	*a*	34	4 . 8 7 5 . 3 . 5 5 6*
	b		5 . 2 8 3 . 5 . 2 3 3
Bartlow		54	9 . 2 5 2 . 6 . 5 7 6
Barton		45	5 . 6 (10) 8 . 3 . 6 6 5
Bassingbourn		34	3 . 8 5 6 . 2 . 6 5 6*
Bottisham		56	4 . 4 4 2 . 2 . 4 5 5
Bourn		35	5 . 3 (10) 5 . 2 . 4 5 6
Boxworth		36	4 . 1 5 2 . 3 . 1 3 4
Brinkley		65	4 . 4 4 4 . 2 . 5 7 5
Burrough Green		65	5 . 3 7 5 . 4 . 3 4 5
Burwell (two parishes)		56	5 . 5 4 5 . 3 . 6 6 6
Caldecote		35	6 . 5 6 5 . 1 . 6 6 4
Cambridge (several parishes)	*a*	45	2 . 2 4 1 . 1 . 2 2 4
	b		8 . 3 8 6 . 4 . 6 6 5
	c		7 . 2 6 4 . 4 . 4 5 3
Carlton / Willingham		65	8 . 1 4 3 . 5 . 4 7 7
Castle Camps		64	6 . 2 4 2 . 4 . 7 9 5
Caxton		35	5 . 3 8 5 . 2 . 2 4 5
Cherry Hinton		45	7 . 4 5 5 . 2 . 6 5 4
Chesterton	*a*	45	5 . 2 5 3 . 5 . 2 4 4
	b		3 . 2 6 3 . 3 . 1 2 3
Cheveley		66	4 . 6 7 5 . 2 . 5 6 6
Childerley, Great / Childerley, Little		36	6 . 2 5 2 . 4 . 4 4 5
Chippenham		66	7 . 4 7 4 . 5 . 7 7 7
Clopton		34	3 . 2 6 1 . 0 . 3 3 3
Comberton		35	5 . 6 7 6 . 2 . 8 8 6
Conington		36	4 . 2 6 2 . 3 . 1 2 4
Coton		45	5 . 6 9 6 . 2 . 5 5 4
Cottenham		46	6 . 4 4 5 . 4 . 7 7 5
Croxton		25	5 . 1 5 3 . 2 . 1 3 4
Croydon		34	3 . 2 7 2 . 1 . 4 5 3
Dullingham		65	4 . 5 7 3 . 6 . 2 2 3
Duxford (two parishes)		44	6 . 1 5 3 . 4 . 3 5 4
Dry Drayton		36	4 . 2 8 2 . 3 . 1 3 4
East Hatley		25	1 . 4 9 2 . 0 . 0 0 3
Elsworth		36	6 . 2 5 4 . 5 . 5 7 6
Eltisley		25	4 . 2 (10) 4 . 2 . 3 4 4
Exning		66	
Fen Ditton		46	7 . 2 8 6 . 6 . 3 4 4

TABLE I (*cont.*)

Parish		*Grid reference*	*Biometrical values*								
Fen Drayton		36	4	2	8	4	5	1	2	4	
Fordham		67	4	6	8	7	2	5	5	4	
Fowlmere		44	7	1	6	2	5	3	3	4	
Foxton		44	6	3	5	2	5	4	5	5	
Fulbourn (two parishes)		55	7	2	6	3	4	6	8	6	
Gamlingay		25	3	7	(11)	6	2	6	6	5	
Girton		46	5	5	6	6	1	4	4	5	
Granchester		45	6	4	(10)	6	4	5	6	4	
Graveley		26	4	2	7	3	5	2	3	3	
Great Abington		54	4	5	6	3	2	6	6	5	
Great Eversden	*a*	35	6	6	6	4	3	7	8	6	
	b		4	7	(10)	7	3	7	7	6	
Great Shelford		45	6	3	5	3	3	7	7	6	
Great Wilbraham		55	7	4	7	4	5	7	8	6	
Guilden Morden		24	4	4	7	4	2	4	4	4	
Hardwick		35	6	2	5	3	4	5	6	5	
Harlton	*a*	35	5	4	10	5	4	2	4	4	
	b		3	9	4	3	1	6	6	5*	
	c		4	7	8	5	2	3	3	4	
Harston		45	4	3	6	4	2	4	4	4	
Haslingfield		45	7	4	5	5	4	8	8	7	
Hatley St. George		25	5	1	7	5	5	3	4	4	
Hauxton		45	6	4	9	5	2	8	8	7	
Helion Bumpstead		64	7	2	4	2	3	4	5	6	
Hildersham		54									
Hinxton		44	6	4	6	5	5	6	6	5	
Histon (two parishes)		46	5	5	8	6	4	7	6	5	
Horningsea		46	5	4	4	4	3	7	7	7	
Horseheath		64	7	3	8	4	4	5	6	5	
Ickleton		44	8	2	4	2	3	7	9	7	
Impington		46	7	2	6	4	4	5	7	5	
Isleham		67									
Kennett		66	6	5	5	4	4	3	3	5	
Kingston		35	4	4	8	5	2	4	4	5	
Kirtling		65	5	4	4	2	2	3	3	4	
Knapwell		36	6	2	6	3	5	3	4	4	
Landbeach		46	6	3	5	4	6	4	5	5	
Landwade		66									
Linton		54	6	4	4	5	7	8	9	7	
Litlington		34	4	8	4	5	2	5	6	7*	
Little Abington		54	5	4	2	5	5	8	8	6	
Little Eversden		35	6	4	4	3	2	7	8	7	
Little Gransden		25	6	2	4	5	5	3	4	4	
Little Shelford		45	5	5	4	3	2	8	8	6	
Little Wilbraham		55									
Lolworth		36	4	2	6	3	3	2	3	4	
Long Stanton (two parishes)		36	3	5	6	4	1	4	4	4	
Long Stowe		35	3	3	6	2	2	2	3	5	

TABLE I (*cont.*)

Parish		Grid reference	Biometrical values									
Madingley		36	5	2	6	3	4	1	2	4		
Malton		34	6	3	3	3	2	6	7	5		
Melbourn		34	4	8	5	6	3	6	5	6*		
Meldreth		34	5	2	6	4	3	3	3	4		
Milton		46	4	5	8	9	2	5	5	5		
Newton		44	4	4	8	5	1	4	4	4		
Oakington		46	6	3	6	4	5	5	7	6		
Orwell	*a*	35	3	8	7	5	2	4	3	5		
	b		2	4	(12)	4	2	(—1)	0	3		
Over		37	3	2	5	1	2	4	4	3		
Pampisford	*a*	44	5	5	6	5	2	8	8	6		
	b		7	2	6	3	6	5	6	5		
	c		4	7	4	5	1	8	7	7*		
Papworth Everard		26	5	2	7	3	5	3	4	3		
Papworth St. Agnes		26	5	3	6	3	4	2	3	4		
Rampton		46	5	4	8	4	0	5	5	5		
Sawston		44	7	3	6	4	5	5	7	6		
Shepreth		34	7	2	4	1	4	5	6	6		
Shingay		34	4	2	4	2	2	2	3	4		
Shudy Camps		64	6	2	4	2	5	5	8	6		
Silverley		76	5	5	7	5	2	5	6	7		
Snailwell		66	4	4	(10)	5	5	4	4	4		
Soham		57	6	4	5	4	2	6	6	5		
Stapleford		45	6	4	5	4	2	7	7	6		
Steeple Morden		24	5	4	6	3	4	2	3	5		
Stetchworth		65	5	4	6	3	2	6	7	5		
Stow cum Quy		56	4	5	5	3	3	4	5	5		
Swaffham Bulbeck		56										
Swaffham Prior (two parishes)		56	4	4	9	7	2	5	6	5		
Swavesey		36	5	2	6	3	4	2	2	3		
Tadlow		24	5	3	5	2	3	3	3	4		
Teversham		45	5	4	4	6	2	7	7	5		
Thriplow		44	6	4	4	4	5	7	7	5		
Toft		35	4	2	5	3	3	1	3	4		
Trumpington		45	4	4	(10)	5	3	4	5	5		
Waterbeach		46	4	4	9	5	4	2	3	4		
Wendy		34	5	3	8	3	4	2	2	4		
Westley Waterless		65										
Weston Colville		65	6	4	6	3	7	3	5	4		
West Wickham		64	8	3	5	2	5	6	7	6		
West Wratting		65	7	3	6	4	5	5	7	6		
Whaddon		34	5	3	7	3	4	4	5	5		
Whittlesford		44	7	3	5	4	3	5	6	6		
Wicken		57	6	6	7	6	4	7	8	8		
Willingham		47										
Wimpole		35	4	2	(11)	3	2	3	4	5		
Wood Ditton		65	6	3	4	5	5	5	6	6		

RESULTS

The mean measurements for each sample are presented in Table I. As before, each character is expressed in terms of a scale of 10 units (0–9), the order of the characters being as cited below. In contrast to the earlier paper, tooth number now follows basal asymmetry; this enables all the tooth characteristics to be grouped together.

The absolute range and size of the scaled unit for each of the eight quantitative characters is as follows:

Length . . .	3–8 cm., 1 unit being 0·5 cm.	
Relative breadth . .	0·40–0·90	1 unit being 0·05
Relative petiole length .	0·00–0·20	„ „ 0·02
Basal asymmetry . .	0·00–0·20	„ „ 0·02
Tooth number . .	50–150	„ „ 10
Tooth breadth . .	3–8 mm.	„ „ 0·5 mm.
Tooth length . .	3–8 „	„ „ 0·5 „
Tooth depth . .	0–5 „	„ „ 0·5 „

In a few cases, characters transcended the range as given above. Rather than alter the scales, which are the same as those used earlier, scaled values greater than 9 and minus values have been used where necessary.

It was found that the information provided by the *G* test did not contribute much to an understanding of the type of variation involved, in particular since practically the entire collection forms a single continuously varying population. Nearly every sample is linked to each other sample by a series of intergrading forms. In the following account, therefore, a procedure suggested in the first paper of this series is adopted instead. The biometrical characters studied are taken as dimensions in an 8-dimensional taxonomic space. The entire collection can therefore be represented as a solid in this space and can be divided into a

TABLE II. *Principal populations and their biometrical ranges*

Group	*Biometrical range*							
BOXWORTH . .	3–5	1–3	4–8	2–4	2–5	1–3	2–4	3–5
SAWSTON . . .	6–9	1–3	4–6	1–5	3–6	4–7	4–9	5–7
ELTISLEY . . .	4–5	2–4	9–11	3–5	2–5	2–4	4–5	4–6
BOTTISHAM . .	3–5	4–5	4–8	2–6	1–4	2–4	3–5	4–5
STAPLEFORD . .	4–7	4–6	4–7	3–5	1–5	5–8	5–8	4–7
GRANTCHESTER . .	4–6	4–7	7–10	6–9	2–4	5–8	5–8	4–6
BASSINGBOURN . .	3–4	7–9	4–5	3–6	1–3	5–6	5–7	5–7*

number of 8-dimensional parallelepipeds, each of which is completely defined in terms of the lower and upper limits of each quantitative character. This subdivision can be done in various ways and as long as the subdivisions correspond as far as possible to biometric discontinuities, no way is necessarily to be preferred to any other. It is also possible to establish either many small subdivisions or a few large ones, depending on the use to which the classification is to be put. For present purposes, seven large subdivisions have been adopted; they are defined in Table II.

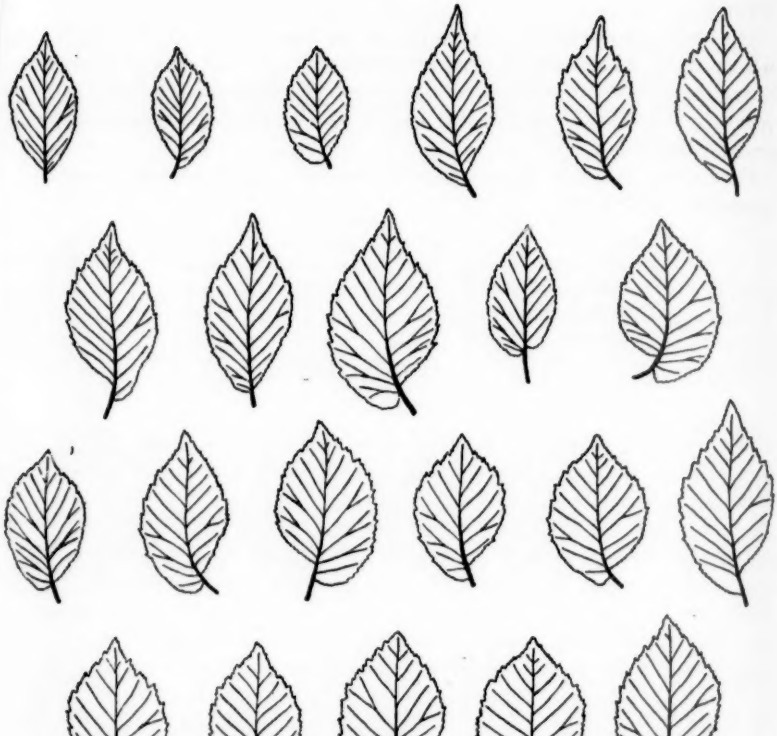


FIG. 2. Specimen elm leaves. Line 1 (reading from left to right), Boxworth (BOXWORTH), Croydon (aff. BOXWORTH), Cambridge[a] (?aff. BOXWORTH), Duxford (intermediate between BOXWORTH and SAWSTON), Castle Camps and Oakington (SAWSTON); line 2, Sawston, Shepreth, and Whittlesford (SAWSTON), Eltisley (ELTISLEY), Girton (BOTTISHAM); line 3, Guilden Morden (BOTTISHAM), Harston (aff. BOTTISHAM), Balsham, Brinkley, Cheveley, and Haslingfield (STAPLEFORD); line 4, Stapleford and Stetchworth (STAPLEFORD), Barton, Comberton, and Grantchester (GRANTCHESTER); line 5, Milton (GRANTCHESTER), Harlton[c] and Gamlingay (intermediate between GRANTCHESTER and BASSINGBOURN), Bassingbourn (BASSINGBOURN, *U. procera*), Dullingham, ? aff.

The following nomenclatural conventions are adopted. Samples are merely referred to by the name of the village in which they were found, e.g. Boxworth. When more than one sample comes from the same locality, they are differentiated by superscripts, e.g. Cambridge[a]. The taxonomic groups into which the total population is subdivided are named after a type sample and written in capitals, e.g. BOXWORTH.

Representative leaves of the entire population are illustrated in Fig. 2. The distribution of each group within the county is shown in Fig. 3.

The area of the county in which elms are frequent is also shown in Fig. 3. It can be seen from this map that elms are abundant in the west and south. They become infrequent or absent along the southern border of the fens, as for example in Willingham or Isleham. They are also infrequent along much of the chalk outcrop in the Newmarket area towards the north-east. The parishes of Soham and Wicken, which are practically surrounded by fenland, have elms in abundance.

TAXONOMIC ANALYSIS

The seven groups recognized will be described in turn. Narrow-leaved elms are taken first, proceeding thence to the broad-leaved forms.

BOXWORTH. This group is composed of the following samples: Abington Piggots, Barrington[b], Boxworth, Chesterton[a], Chesterton[b], Conington, Croxton, Dry Drayton, Fen Ditton, Graveley, Lolworth, Long Stowe, Madingley, Meldreth, Papworth St. Agnes, Papworth Everard, Shingay, Swavesey, Tadlow, Toft, and Wendy. The group is confined to the western half of the county. There are two principal areas: (1) the boulder clay plateau to the north-west of Cambridge, on which this is the characteristic elm, and (2) the valley of the Western Cam. It is interesting that, although this group occurs as far east as Chesterton, it does not cross the Lower or Southern Cam.

The leaves of this group are narrow and the teeth small. The number of teeth is variable and can be quite high. The leaves are characteristically rather dark green in colour, and the upper surface, though not rough, has somewhat of a matt feel. The Hatley St. George, Knapwell, Little Gransden, and Over samples differ only slightly from typical members of this group. The depauperate Clopton and Croydon elms are probably related; both villages occur on the northern side of the Western Cam.

Cambridge[a] is the solitary example of a unilateral elm (commonly referred to as *U. plotii* Druce) encountered in the area. It may be that this sample has no connexion with the BOXWORTH group and has been introduced from outside the county; on the other hand, the possibility cannot be ruled out that Cambridge[a] is a unilateral derivative of the BOXWORTH group, especially as the nearby Chesterton elms, also in this group, show a tendency towards the unilateral habit. *U. plotii* is commonly regarded as a good species. There are grounds for supposing, however, that the unilateral habit may have arisen independently in a number of different localities, in all cases from narrow-leaved forms. An instance is provided by the unilateral elms encountered among the narrow-leaved elms of the Stort valley in Hertfordshire (unpublished observations). If the unilateral habit is

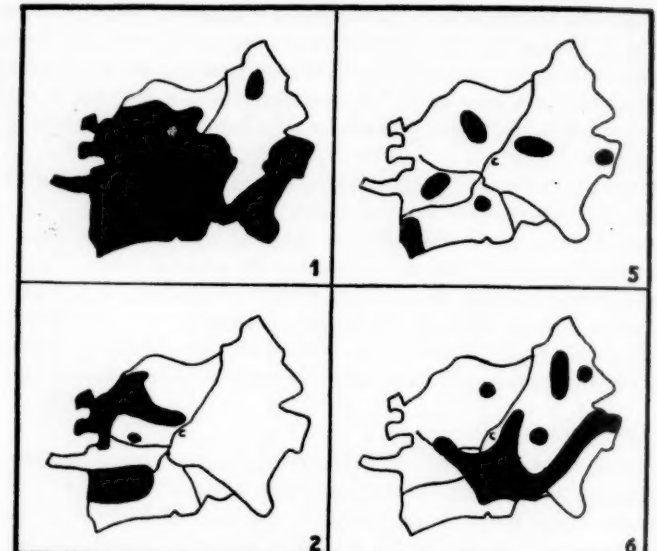


FIG. 3. Distribution maps. (1) Area in which elms occur frequently; (2) BOXWORTH; (3) SAWSTON; (4) ELTISLEY; (5) BOTTISHAM; (6) STAPLEFORD; (7) GRANTCHESTER; (8) BASSINGBOURN (*U. procera*).

polyphyletic, it hardly seems proper to employ it as a specific criterion, in which case *U. plotii* would have to be rejected as a species. The status of the Cambridge[a] unilateral elm is, however, uncertain and further investigation of the BOXWORTH

elms most nearly resembling it is required before its relationships can be definitely decided.

SAWSTON. The samples constituting this group are Carlton, Castle Camps, Childerley, Foxton, Fulbourn, Great Shelford, Hardwick, Helion Bumpstead, Ickleton, Impington, Landbeach, Oakington, Pampisford[b], Sawston, Shepreth, Shudy Camps, West Wickham, West Wratting, Whittlesford, and Wood Ditton. These elms are found in four main areas and it is not certain that these four populations are of identical origin, especially as the differences in location are accompanied in some cases by biometrical distinctions. As can be seen from Fig. 3, the four main areas occupied by the group are (1) the valleys of the Upper Cam, (2) the south-east corner of the county, (3) the flat land to the north of Cambridge, and (4) some villages in the western boulder-clay plateau.

The leaves of this group are narrow but much larger than in the BOXWORTH elms and the teeth are also larger. The colour of the leaves is usually bright green and the lamina is often undulate rather than coplanar. Two closely related samples were collected at Bartlow and Horseheath, both in the south-eastern area mentioned above. Transitional forms between this group and the BOXWORTH elms are exemplified by the Duxford and Fowlmere samples from the south of the county and by sample Cambridge[c].

ELTISLEY. This is one of the smaller groups, comprising the Bourn, Eltisley, Harlton[a], Snailwell, Trumpington, Waterbeach, and Wimpole samples. It is chiefly encountered along the upper reaches of the Bourn Brook.

Its distinguishing characteristics are the narrow leaves with very long petioles. The East Hatley and Orwell[b] elms appear to be related, the chief difference being their very small teeth. The Caxton elm is intermediate between this group and the BOXWORTH group.

BOTTISHAM. The villages from which the elms of this group come comprise Arrington, Bottisham, Girton, Guilden Morden, Kingston, Kirtling, Long Stanton, Newton, Steeple Morden, and Stow cum Quy. The distribution of this type is scattered and the various populations constituting it may not be closely related; the four main populations are biometrically distinct.

The leaves of this group are intermediate in all respects with no extreme characteristics. The elms from Burrough Green, Harston, Kennett, Rampton, and Whaddon only differ slightly.

STAPLEFORD. This large group includes the following samples: Ashley, Balsham, Brinkley, Burwell, Caldecot, Cherry Hinton, Cheveley, Chippenham, Cottenham, Great Abington, Great Eversden[a], Great Wilbraham, Haslingfield, Hinxton, Horningsea, Little Eversden, Little Shelford, Pampisford[a], Silverley, Soham, Stapleford, Stetchworth, and Thriplow. There are three main locations: (1) the valleys of the Upper Cam, (2) the villages along the top of the chalk outcrop in the south-east of the county, and (3) a smaller area surrounded by fen towards the north-east.

These elms are distinguished from the SAWSTON group by their broader leaves. The teeth are large; petiole length and asymmetry are moderate. The samples from Linton, Little Abington, and Teversham are probably related and come

from the same general area. The Malton elm should probably be assigned either near this group or near the SAWSTON group.

GRANTCHESTER. There are nine samples in this group: Barton, Comberton, Coton, Fordham, Grantchester, Great Eversden[b], Histon, Milton, and Swaffham Prior. It is mainly confined to the lower reaches of the Bourn Brook and the area immediately to the north of Cambridge.

The salient feature of the group is the high asymmetry. The leaves are broad, the petiole usually long, and the teeth large. Related samples include Cambridge[b] and Wicken. The Babraham and Hauxton elms are intermediate between this group and the STAPLEFORD group.

BASSINGBOURN. This is one of the smaller groups and comprises the Bassingbourn, Harlton, Litlington, Melbourn, and Pampisford[c] elms. It is confined to the south-west border of the county.

All the preceding groups were smooth-leaved. The present group has very broad scabrous leaves and large teeth. It is typical *U. procera* Salisb. Four samples are intermediate between this group and the GRANTCHESTER group, all coming from areas in which both *U. procera* and smooth-leaved elms are present. Barrington[a] resembles the BASSINGBOURN group in all respects save its long petiole. Harlton[c] and Orwell[a] have smooth or only very slightly rough leaves, but these are as broad as typical *U. procera* though the petiole is long and the teeth small. The Gamlingay elm has smooth but very broad leaves with large teeth and an extremely long petiole.

The only samples that remain for consideration are from Fen Ditton, Weston Colville, and Dullingham. The affinities of these are quite uncertain. The first has large, narrow, highly asymmetrical leaves with numerous small teeth. The other two are both distinguished by their high tooth numbers.

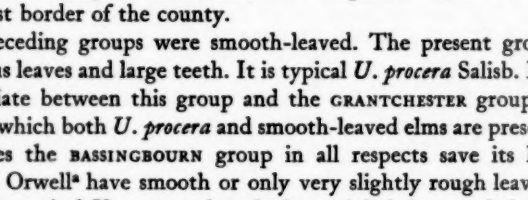


FIG. 4. Affinities of the groups.

It is clear from the foregoing that the range of variation of the village elms in such a comparatively small area as southern Cambridgeshire is very great. It is also the case that the groups described are not sharply demarcated from each other and are connected in many cases by intermediate forms. The principal affinities of the groups are set out diagrammatically in Fig. 4.

The group that stands most apart from the others is BASSINGBOURN, which is typical *U. procera*. All the other groups pertain to *U. carpinifolia* Gled. sensu

Rehder (1938). The inadvisability of splitting this species further, one of the conclusions of the earlier paper, is confirmed by the data presented here. However, intermediates between *U. procera* and the GRANTCHESTER group of *U. carpinifolia* elms were found in the area of contact of these two groups. It appears to be generally supposed that these two species do not hybridize. This may not be so in this area.

Doubts on the specific distinctness of *U. plotii* were raised in the account of the BOXWORTH group, but a full discussion of this question is best deferred till other populations of unilateral elms have been described.

Though it appears inadvisable to split *U. carpinifolia* into minor species, there is no doubt, as Table I shows, that the species is extremely variable and that subordinate taxa can be recognized. It is not suggested that the groups described here should be accorded varietal status. In all cases there is a practically continuous transition from any one group in the groups nearest allied. The groups in fact are best regarded as segments cut out of a taxonomic continuum. They are defined so as not to overlap biometrically. However, it would be possible to represent the range of variation with the cuts made elsewhere. In any case, only further intensive study of the range of variation within single parishes could provide a definitive description of the exact relationships of the various populations.

The range of variation encountered suggests the possibility that we are dealing with a hybrid swarm and that some sort of analysis of introgression, as worked out by Anderson (1949), might be applicable. However, this is not very easy in the present case, in particular because it is uncertain which groups should be regarded as ancestral to the others. It is safe to assume that the BASSINGBOURN group (*U. procera*) is not derived from any other in the area since it has two characteristics, very broad lamina and scabrosity, lacking in all the others. Large lamina size is confined to the SAWSTON and STAPLEFORD groups and is associated with large tooth size. It is probable that one or other of these groups is an ancestral type. The characteristics found in neither the BASSINGBOURN or SAWSTON-STAPLEFORD groups include long petiole, high asymmetry, and small teeth, and since none of the remaining groups exhibit more than two of these characteristics in common, it seems necessary to postulate a minimum of two further ancestral groups, either BOXWORTH and GRANTCHESTER, or less likely ELTISLEY and GRANTCHESTER. The extensive distribution of the BOXWORTH group compared to the restricted area of the ELTISLEY group renders it more likely that the former is the ancestral group. So, if the range of variation is to be regarded as consequence of hybridization, a minimum of four ancestral groups, BOXWORTH, GRANTCHESTER, SAWSTON-STAPLEFORD, and BASSINGBOURN (*U. procera*), would seem necessary.

However, it is quite uncertain what role hybridization has played in the variation of English elms. Seedlings are only produced in exceptionally favourable seasons and reproduction is nearly always vegetative. The intermediates between *U. carpinifolia* and *U. procera* suggest that hybridization has occurred locally, but experimental evidence on this point is much to be desired.

Recently doubt has been cast on the significance of introgression as a determinant of population variability (cf. Barber and Jackson, 1957). It is possible that

the observed variation of the Cambridgeshire elms is a consequence of mutation rather than hybridization or to some combination of the two. The vegetative mode of reproduction of all the elms considered here is conducive to the preservation of somatic mutations. If mutation has been of major significance, the observed variation admits of a greater diversity of explanation than if introgression alone is involved. Of the four putative ancestral groups mentioned above, BASSINGBOURN (*U. procera*), BOXWORTH, and SAWSTON-STAPLEFORD differ from each other in a whole series of characteristics, and it seems unlikely therefore that they have differentiated *in situ* from a single originally uniform population. The status of the GRANTCHESTER group is less certain since it could conceivably have arisen by mutation from the SAWSTON-STAPLEFORD group, from which it differs only in the longer petiole and greater asymmetry.

There is strong evidence for introgression from wild *U. glabra* into *U. carpinifolia* elsewhere in England. *U. glabra* occurs throughout Cambridgeshire, especially on upland calcareous soils and by the sides of streams but is seldom frequent. No indications of introgression in this area have been obtained.

If we now agree to take the minimum number of introductions of elms as three, represented by the BASSINGBOURN (*U. procera*), BOXWORTH, and SAWSTON-STAPLEFORD groups, it is pertinent to inquire as to their origins. *U. procera* is widespread to the south and west of Cambridgeshire and there is every reason to suppose that it was introduced from the adjoining parts of Hertfordshire. There is insufficient data on *U. carpinifolia* in other areas to justify speculation as to the origin of the BOXWORTH and SAWSTON-STAPLEFORD groups. However, the distribution of these within the county suggest that the BOXWORTH group may have come from farther west while the SAWSTON-STAPLEFORD elms, if they were introduced from an adjacent region, most likely came from the east.

HISTORICAL ANALYSIS

It was surmised in the preceding paper of this series that, as far as East Anglia is concerned, *U. glabra* is probably a relic of the indigenous forest flora, *U. carpinifolia* was introduced from the east some time during the Neolithic, Bronze, or Iron Ages, and *U. procera* was introduced from the west at some quite uncertain date.

The historical problem can now be advanced a stage further. The earliest indirect historical evidence concerning elms in Cambridgeshire is provided by place names. Elmeney, in Waterbeach parish, mentioned as early as the twelth century, and Olmstead, in Castle Camps parish, mentioned in the thirteenth century, are both regarded by Reaney (1943) as derivatives of the Teutonic root *elm*. In addition, Elm, in the Isle of Ely, is cited in the Anglo-Saxon Chronicle under the year A.D. 656, while Elmdon, just over the county border in Essex, is first encountered in the Domesday Survey. While there is at least a strong probability that these two names are based on *elm*, there is a possibility in each case that they may have been based on personal names (Reaney, 1935 and 1943).

In the south of the Isle of Ely, two parochial names, Witcham and Witchford, are held by both Reaney (1943) and Ekwall (1947) to be based on the second

Teutonic root for elm, *wice*. Finally, it is possible that Lymage, just over the Huntingdonshire border, is derived from *lem*, the Celtic root for elm (cf. Mawer and Stanton, 1926).

The earliest direct references to elm located so far are in the manorial muniments preserved in Sawston Hall. We learn from the Sawston Court Rolls that John Frankeleyn cut down four 'plantas de wych' in 1360. A little later, 1391, the Whittlesford Court Rolls report two cases of waste involving 'arbores vocatas wyches'. It will be noted that the term used for elm is *wych*. As shown in the earlier paper, this did not, in the Middle Ages, denote *U. glabra* in particular, but any elm. It is likely in the present case to refer to the SAWSTON group of *U. carpinifolia*.

Two medieval references to elms have been published by Hailstone (1873). They occur in a terrier of lands of the priory of Anglesey, which owned a piece of land 'apud le wych' in Bottisham and another 'ny of the whych' in Barnwell, Cambridge. It is recorded that elms were felled at Magdalene College, Cambridge, in 1586 (Purnell, 1904).

General statements on the extensive distribution of the elm in Cambridgeshire are made by Standish (1615) and Vancouver (1794).

A particularly interesting though rather late reference to elms occurs in a parish register of Wendy (Jones, 1903). A note dated 1637 states that 'the timber trees with other witch and elm on y^{e} outside of y^{e} church yard which lys south and west belongs to y^{e} vicar'. A distinction seems to be implicit here between *wych* and *elm*. The common village elms of Wendy pertain to the BOXWORTH population of *U. carpinifolia*. However, *U. procera* is frequent in neighbouring parishes and a revisit to the village revealed a specimen of this species by the churchyard wall. It is possible therefore that in the seventeenth century in parishes where the two species intermingled the term *wych* was appropriated to *U. carpinifolia* and *elm* to *U. procera*. This would fit in with the contemporary usage in the second edition of Gerard's Herball (1633), where *wych* is one of the names given for the smooth-leaved elm but not for *U. procera*.

A last line of historical evidence is provided by old trees, three of which, Cambridge^{b}, Melbourn, and Stetchworth provided samples for the present survey. Cambridge^{b} is the last survivor of the row of elms planted on Christ's Piece in the seventeenth century and marked on the Cambridge (1688) map by Loggan. The Melbourn sample is from a sucker of the Melbourn elm, a well-known landmark of great age in the early nineteenth century, an illustration of which is sewn on to the map accompanying the Melbourn (1839) enclosure award. The Stetchworth elm is specially marked on the Stetchworth (1770) map and was presumably of some note at that time.

The above data provide satisfactory evidence that *U. carpinifolia* was widespread in Cambridgeshire in the later Middle Ages and *U. procera* was present in the southern part of the area. The place-name evidence seems to attest the presence of *U. carpinifolia* in early Anglo-Saxon days and to require a date of introduction that can hardly be later than Roman. Moreover, the overall distribution of *U. carpinifolia* in England, which occurs principally in East Anglia and

the north-east Midlands, with outliers in Kent, the Sussex coast, southern Hampshire, and Glamorgan, bears no apparent relationship to Roman features and strongly suggests some earlier cultural pattern, of which Iron Age B is perhaps the most likely.

It would thus appear probable that *U. carpinifolia*, as represented by the SAWSTON-STAPLEFORD group, is at least of Roman age in the county and that it was either introduced directly from Europe into the county via the Wash in the Iron Age or introduced in Iron Age or Roman times from some other locality in eastern England. It is doubtful whether the BOXWORTH group is of the same age, for it is principally found in areas in the west of the county which both archaeological evidence and place-name forms indicate as of late Anglo-Saxon settlement. The date of introduction of *U. procera* cannot be fixed yet with any precision but was certainly not later than medieval.

LITERATURE REFERENCES

Anderson, E. (1949): *Introgressive Hybridization.*

Barber, H. N., and Jackson, W. D. (1957): 'Natural Selection in Action in *Eucalyptus*.' *Nature, Lond.* clxxix. 1267.

Cambridge (1688): *Nova & accuratissima celeberrimae Universitatis Oppidique Cantabrigiensis ichnographia*, by D. Loggan.

Ekwall, E. (1947): *The Concise Oxford Dictionary of English Place Names*, ed. 3.

Gerard, J. (1633): *Herball*, ed. 2.

Hailstone, E. E. (1873): 'The History and Antiquities of the Parish of Bottisham.' *Camb. Antiq. Soc. Oct. Ser.* xiv–xvi.

Jackson, J. E., and Ross, E. L. (1955): 'Extended Tables for Use with the "G" Test for Means.' *J. Amer. Stat. Assoc.* l. 416.

Jones, W. (1903): 'Extracts from the Parish Registers, Wendy, Cambs.' *E. Anglian*, x. 134.

Mawer, A., and Stenton, F. M. (1926): *The Place-names of Bedfordshire and Huntingdonshire.*

Melbourn (1839): *Plan of the Parish of Melbourn in the County of Cambridge, as Alloted and Awarded by the Commissioners Appointed to Inclose the Same*, by A. Watford. (Cambridge University Library. Photostat Copy Maps bb. 53(1). 93. 75–82.)

Purnell, E. K. (1904): *Magdalene College.*

Reaney, P. H., (1935): *The Place-names of Essex.*

—— (1943): *The Place-names of Cambridgeshire and the Isle of Ely.*

Rehder, A. (1938): 'New Species, Varieties and Combinations from the Collections of the Arnold Arboretum.' *J. Arnold Arbor.* xix. 264.

Richens, R. H. (1955): 'Studies on *Ulmus*. I. The Range of Variation of East Anglian Elms.' *Watsonia*, iii. 138.

Sawston Court Rolls. (Sawston Hall.*)

Standish, A. (1615): *New Directions of Experience Authorized by the Kings Most Excellent Maiesty, as may Appeare, for the Increasing of Timber and Fire-wood.*

Stetchworth (1770): *A Plan and Survey of the Lordship of Stetchworth in the County of Cambridge*, by G. Salmon. (Cambridge University Library MS. Plans 345.)

Vancouver, C. (1794): *General View of the Agriculture in the County of Cambridge.*

Whittlesford Court Rolls. (Sawston Hall.*)

* Access to these records was given by kind permission of Capt. R. E. Huddleston. The transcriptions were provided by Mr. T. F. Tevershaṁ.

METHODS OF LIGHT INTENSITY MEASUREMENT IN FOREST STANDS

I. *Instrumentation*

By R. D. CONNOR

(*Department of Natural Philosophy, University of Edinburgh*)

SUMMARY

The paper describes shortly the instruments in use and the preparatory work of calibration and testing of equipment in the laboratory. The photographic, uranium oxalate technique, actinometer, and photo-electric methods using barrier-layer cells are all reviewed and the theory and practice of the barrier-layer cells described in detail including the action of the voltameter. The danger of cell deterioration is covered and certain difficulties arising in the field are considered.

SOME years ago the writer was asked by the Department of Forestry of the University of Edinburgh to suggest to them a method of determining the total light energy falling on the forest floor over a period of time corresponding to the growing season. These measurements were primarily designed by the Department of Forestry to produce information on the optimum amount of light required to foster the natural regeneration of certain tree species. Clearly, if the density of the trees is too great, there will be too little light to permit the young tree to thrive, while if thinned too heavily, more light than is necessary reaches the ground and the ground flora expand rapidly—again to the detriment of the regeneration—while the area is supporting less timber than it might have done.

An instrument was therefore required to integrate the light received over a period of time. It has to be robust enough to stand up to several months' exposure at a time. It must require little attention and be self-contained while giving a reading error not greater than ± 10 per cent., and it must be of low cost so that several such units could be built up on a slender research grant. When it is remembered that of physical measurements photometry is one of the most difficult even under laboratory conditions, it will be appreciated that this instrument would have to meet fairly stringent requirements.

There were four main methods available in principle, viz. the photographic method, the uranium oxalate technique, the use of actinometers, or the use of some sort of recording photocell.

1. *The photographic method*

In 1950 the writer sought the advice of the Photographic Department of the Radio Research Establishment (Ministry of Supply) at Great Malvern, on the possibility of using a simple technique with photographic film. Their report indicated that a camera gun fitted with several apertures and neutral filters could be used for this work, provided the light reaching the film was reduced in intensity

by a factor of 400 million, in which case commercial film could be used. However, the complexity and cost of the camera, to say nothing of the difficulty of obtaining uniformity in the development process over long periods of time, led to the rejection of this method.

2. *Uranium oxalate technique*

The solution of uranyl oxalate in water is dark and opaque and the molecule dissociates into carbon dioxide, carbon monoxide and water under the influence of light. The quantum yield of this process is known (Bowen, 1946; Laighton, 1941). Commencing with a solution of known concentration, a simple titration of the exposed solution against a standard solution of potassium permanganate in accordance with the ordinary procedures of volumetric analysis gives the amount of oxalate remaining and hence by subtraction a measure of the light absorbed by the solution. Provided the solutions are regularly stirred this method would have been quite suitable. In fact it was not used as the difficulty of stirring was too great under operational conditions, and the solution was too sensitive for our purpose.

3. *The actinometer method*

After this work had begun it was learned that actinometers had been used in France for this type of work (Roussel, 1953). An actinometer consists basically of two concentric glass balls of different radii, the inner one containing a quantity of alcohol or other volatile liquid. The space between the two spheres is evacuated. The spheres are mounted at the top of a vertical tube about a yard long from which a narrow communicating tube passes inwards through both sphere walls, up through the alcohol, finally terminating with an open end in the space above the liquid. When solar radiation strikes the bulbs it passes, for the most part, through the outer bulb, through the vacuum and is partially absorbed by the inner bulb or its liquid contents, whereupon the temperature rises in this part of the apparatus. The alcohol evaporates from the bulb but recondenses in the tube which is in contact with and at the temperature of the outside air and is therefore not thermally insulated as is the inner sphere. The heat absorbed by the inner sphere and its contents provides the latent heat of vaporization for a certain mass of alcohol which distils into the cooler tube where it collects as liquid. The volume which distils each day is a measure of the total incident radiation.

This apparatus requires a little attention daily. It is not available commercially but can be constructed by a glass-blower. At the time this service was not readily available, so the fourth possibility was examined closely.

4. *The photo-electric method*

Ordinary photocells with recording microammeters were ruled out because of their expense and the need of an electrical supply for the cell. On the other hand, barrier-layer cells need no battery and give a considerable current output which is proportional to the light intensity over a wide range. A barrier-layer cell consists of a base plate of metal on to which a selenium compound is deposited. A

very thin layer of metal is evaporated on to this so that a metal-selenium-metal sandwich results. The evaporated layer is transparent to light but is sufficient to make electrical contact with the upper surface of the selenium compound. When light quanta strike the cell, electrons are released from the compound which pass to the metal film making it negative with respect to the selenium and the base plate. A current will therefore flow round an external circuit if one is connected. The electrons cannot return directly to the compound from the metal film owing to the action of the boundary layer between the two which creates an electrical 'barrier' in this direction. The current is proportional to the light intensity from zero up to a value determined by the resistance of the external circuit. Thereafter the current output rises less steeply with increasing light intensity. The smaller the series resistance the longer is the region of proportionality.

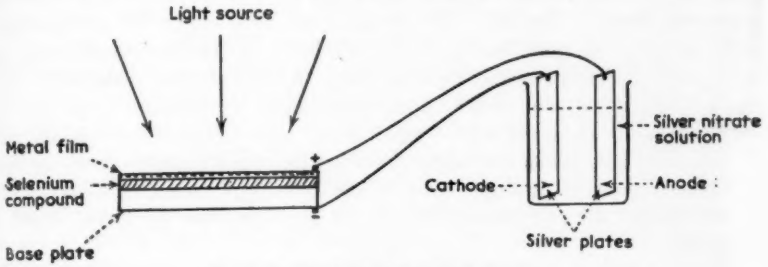


FIG. 1. Barrier-layer cell and voltameter.

To integrate the light intensity with respect to time requires a device of low resistance connected to the barrier-layer cell which can integrate current with respect to time, i.e. which can record the total charge passed in a given period of time. Such a device is a voltameter in which a certain constant mass of metal is transferred from one plate or electrode to the other by the passage of one coulomb of charge. A silver voltameter is the most suitable. It consists of two silver plates dipping into an aqueous solution of pure silver nitrate. Silver has the largest electrochemical equivalent of all the common substances, i.e. it gives the largest mass of transferred material per coulomb, viz. 0·001118 g. per coulomb. Moreover, it has a very low resistance.

The arrangement recommended to the Forestry Department is that shown in Fig. 1. It has been under test for five years and operational for a further two. Several difficulties arose in the trials but these have been overcome and it is believed that reliable results can be obtained if the proper precautions are taken.

Experimental technique. Barrier-layer cells are commercially available. The type B cell is suitable for this work and the makers' data show the spectral response to be that given in Table I.

The maximum response occurs at the same wavelength as that for the human eye, viz. 0·565 μ.

Before use, each cell was calibrated against a pair of photo-cells which gave a direct reading of the light intensity in foot-candles (f.c.). The light source was a

glass high pressure mercury vapour lamp, noted for the stability of its light output. A 9-ohm Unipivot microammeter shunted with a 1-ohm standard resistance was connected to the cell, which was placed adjacent to the two photo-cells. Calibration was effected by adjusting the distance of the cells relative to the lamp so that the range of light intensity 0–125 f.c. could be examined and a graph of microamperes against foot-candles drawn for each cell. New cells were always

TABLE I. *Spectral response*

Wavelength (μ) . . .	0·40	0·45	0·50	0·55	0·60	0·65	0·70
Type B cell . . .	0·36	0·71	0·90	0·98	0·87	0·31	0·02
Human eye . . .	0	0·04	0·30	0·97	0·64	0·12	0

linear in this range of light intensity while cells which were one or more years old sometimes showed a deviation from linearity at about 100 f.c. No cell deviating prior to 70 f.c. was used. Ideally all the cells in use at one time should yield the same graph of current against light intensity. In practice some variation in slope was evident, but if one cell was chosen as standard, a correction factor (one for each cell) can be obtained at once which would make all the others coincide with the standard one. When evaluating the integrated light intensity from the mass of silver transferred, multiplication of the individual masses of silver by this factor brought the performance of each cell into agreement with that chosen as standard.

After calibration each cell was covered with a neutral density filter (Kodak N.D. 2–0) which allowed 1 per cent. of the incident light to reach the cell itself, and the covered cell was enclosed in a flat perspex box. The cell was therefore sealed off from the atmosphere. The filter is needed to protect the cell from any shafts of direct sunlight, having an intensity of 5000 f.c. or more, which might penetrate gaps in the foliage and reach the cell. An unprotected cell would be overrun and paralysed by such an intensity, perhaps for several days, and should it recommence operation it would be on a much reduced current-intensity relation so that its calibration would be meaningless and the results obtained worthless. The protected cell, even in direct sunlight, is still operating on the linear portion of its curve and functions normally. Naturally, the current from a protected cell is normally small but if left operating for a two-month period, the mass of silver transferred might be as much as 600 mg. for a control cell in the open or 1–10 mg. for a cell in a dense stand, with lighter stands giving intermediate results.

The cell must be sealed up in perspex or other transparent box, for moisture causes the rapid deterioration of the cell.

A few yards of flex carries the current to the voltameter itself which consists of a beaker (150 c.c.) containing two silver plates supported by a double cork, in aqueous silver nitrate solution. The double cork was required as it was found necessary in the course of field trials to exclude the atmosphere from the solution. It would appear that the methane produced by the decomposition of vegetable matter on the forest floor is oxidized by oxone in the air to formaldehyde which

causes the solution to decompose. Rigorous exclusion of the air prevents this deterioration.

The solution itself consisted of 10–15 g. of pure silver nitrate dissolved in 100 ml. of pure water. The water used must be completely free from chlorine or dissolved chlorides to avoid the precipitation of silver chloride. Doubly distilled water was the usual degree of purity employed in this work. Stock solutions can be kept for lengthy periods in dark bottles. The skin is quickly discoloured and clothes stain if any solution is allowed in contact with them.

The silver plates, approximately $2 \times 1\frac{1}{2}$ inches, weighed originally about 25 g. each. Prior to each weighing the surface was roughened by grinding with carborundum, for with smooth plates the deposition of silver occurred as a fern-like crystalline growth from sharp edges and corners. With rough plates the deposition appeared as solid blisters of firmly adhering crystaline metal in the central regions of the plate. With such a deposit there was little danger of loss of silver.

The plates were weighed to the nearest 0·1 mg. on a sensitive balance, and after two months would be replaced by a fresh set. The originals would be brought into the laboratory, washed and dried, and re-weighed to establish the mass of silver transferred. After multiplication by the correction factor, the ratio of the weights so obtained to that of an instrument in the open (the control) gave the relative light in the various stands. Naturally, each instrument only recorded the light reaching the relatively small area of the sensitive surface of the barrier-layer cell. To get a reliable figure for a given stand a number of instruments should be positioned at random and the average taken as representative of that stand. While ideally each cell should have its own voltameter, a number of factors militated against this in the present work. Instead, a number of cells were laid down in a given plot and each was connected in parallel across a single voltameter, with care to ensure that all the leads of the same polarity were connected together.

The weight of silver transferred was correspondingly greater, thus increasing the accuracy while at the same time producing an average value for the stand in question. The disadvantage of this arrangement is that the failure of one cell or cable, or the failure of the single voltameter for any reason, causes the loss of the reading for that stand for the two month period. Where possible, an individual voltameter for each cell is to be recommended.

The perspex boxes require cleaning daily. Bird droppings, leaves, &c., on the cells so reduces the light reaching the cell as to falsify the results completely.

The use of cork in the voltameters is not ideal. A glass or plastic beaker with a lid having a ground joint and the electrical leads sealed into it would be much better. At present these are too costly for us.

At first sight it would appear that this is a very simple arrangement for measuring the integrated light under woodland conditions. While this is true, it is necessary to point out that both the cell and the voltameter are far from simple in their detailed physical and chemical behaviour which was examined in some detail before commencing the field trials in order to be sure that the instruments were giving true reading.

The action of the voltameter. A graph of current through one of the silver

voltameters against the potential difference (P.D.) developed between the plates is shown in Fig. 2. At low P.D. the current rises exponentially giving a straight line for the graph of log (current) against P.D. (Fig. 2). At higher P.D.'s the current rises more and more linearly until at about 1 milliampere the current-P.D. graph (not shown) is straight, representing an effective resistance of the order of 10^{-3} ohms between the plates. The conductivity of silver nitrate at all concentrations is known and for the voltameters described here the expected resistance between the plates is about 2×10^{-3} ohms, in good agreement with that determined from the graph.

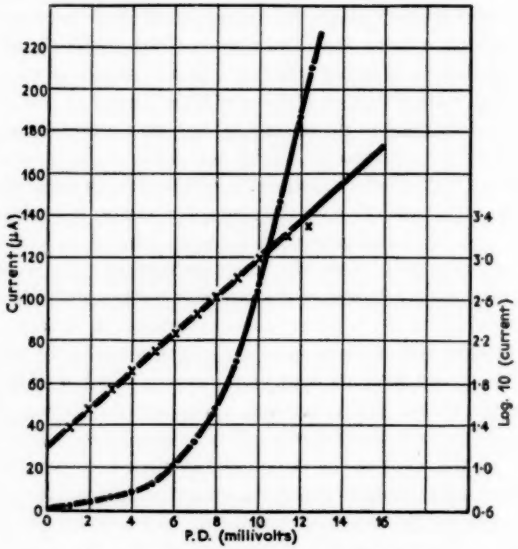


FIG. 2. Current against potential difference.

The exponential behaviour at low currents shows that the equivalent circuit of the voltameter is a resistance in series with an electromotive force (e.m.f.), the latter being so directed as to try to oppose the passage of current through the voltameter. This e.m.f. is known to be fairly complex in its nature but for the most part it is occasioned by the ion concentrations changing in the vicinity of the silver plates. It is therefore a function of the current through the voltameter. In effect then, the voltameter behaves as though it were also a cell of low e.m.f. The D.C. resistance is low and nearly the entire P.D. at low currents is occasioned by this opposing e.m.f. which is never greater than 13 millivolts at a current of 200 microamperes (Fig. 2). A protected barrier-layer cell connected to a voltameter will seldom if ever present a P.D. greater than 20 millivolts between the plates and if all this is assumed to be occasioned by the cell-like action of the voltameter we have to inquire what effect this will have on the instrument's operation.

The barrier-layer cell is essentially a current producing agency. Its open current

voltage is about 200 millivolts even at weak illumination while the figure for a protected cell in sunlight is about 400 millivolts. This voltage will easily overcome the voltameter's reverse e.m.f. At low illumination when the reverse effect is much smaller, the cell is even less disturbed. It can be taken therefore that unless the highest accuracy is required, the action of the voltameter does not preclude the successful operation of the instrument.

The action of the barrier-layer cell. The cosine effect. It is a principle in photometry (Lambert's cosine law) that the intensity of illumination of a surface for a given beam of light varies as the cosine of the angle between the beam and the

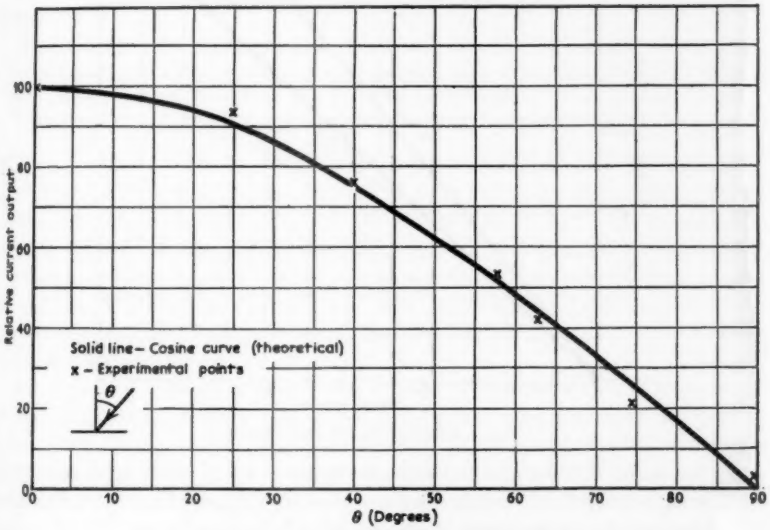


FIG. 3. Deviation of experimental points from cosine curve.

vertical to the surface. It has been found that barrier-layer cells deviate somewhat from this law (Pleijel and Longmore, 1952) and thus introduce an error into the reading, for the light reaching a cell under operational conditions comes from all directions. However, it is known (ref. above) that the interposition of a matt perspex plate between the cell and the light improves the situation. Fig. 3 shows the experimental points taken with a boxed cell against the ideal cosine curve. It will be seen that the deviation is not serious considering the working limits of accuracy, even though the perspex is not matt.

Deterioration of the cell. The graph of current output against light intensity for a cell which has been in use for a year or so is usually not so steep as that obtained for a new cell. Fig. 4 contrasts the performance of a new cell with that obtained a year later from the same cell. It is therefore to be recommended that each cell has its response checked before and after a period of use and if any change has occurred the mean can be taken as representing the actual overall performance.

Effect of parallel connexion of the cells. Tests were carried out with three identical cells to ensure that when connected in parallel, the total current was the sum of the individual currents. It was found that this was so to within a few per cent. This means that the effective reverse resistance of the cells is high and a separate measurement of this quantity showed it to be of the order of a megohm.

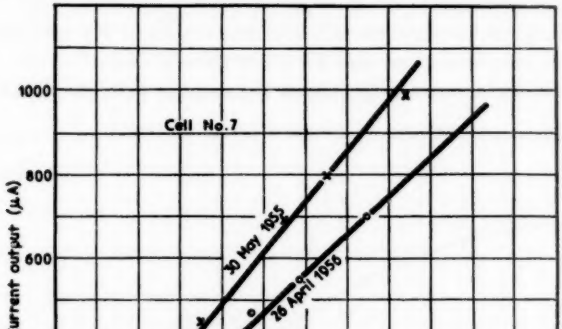


FIG. 4. Variation in cell performance.

Future work. The use of the barrier-layer cells and of other light measuring instruments in this field are described in a separate paper by Dr. W. A. Fairbairn who has been the prime mover in this work.

LITERATURE REFERENCES

Bowen, E. J. (1946): *Chemical Aspects of Light*, Appendixes IV and V, 2nd edition.

Laighton, W. A. (1941): *Photochemistry of Gases.*

Pleijel, G., and Longmore, J. (1952): *Journal of Scientific Instruments*, xxix. 137.

Roussel, L. (1953): 'Recherches théorique et pratiques sur la répartition en quantité et en qualité de la lumière dans le milieu forestier, influence sur la végétation.' *Annales de l'École Nationale des Eaux et Forêts*, tome xiii, fascicule 2.

METHODS OF LIGHT INTENSITY MEASUREMENT IN FOREST STANDS

II. *The Use of Light Measurement Instruments in the Field*

By W. A. FAIRBAIRN

(*Department of Forestry, University of Edinburgh*)

SUMMARY

Recent developments are discussed and the use being made by the Department of Forestry, University of Edinburgh, of the photographic photometer, the luxmeter, and the barrier-layer cell is described separately in detail and illustrated by photographs. The use of filters is considered and a note added on the position reached by research into the problem.

IN spite of the difficulties in the measurement of solar radiation there has been widespread interest and considerable activity in this aspect of research in recent years. The importance of light intensity is now realized not only by biologists but also by industrialists, educational and medical authorities, architects, mining engineers, and many others. The increased interest in light measurement has led to the production of more reliable and much more accurate instruments in the last decade, so that the research worker has now much better equipment available than even a few years ago.

In the field of biology, as in other fields, photometry has become of importance and a widespread interest is now shown in the measurement of light intensity in forest conditions as Roussel (1956) has recorded. This subject has been investigated by a number of forest research workers in recent decades. The restricted progress made in the past was largely due to the limitations of equipment and instruments. An examination of present-day literature on light measurement in forestry shows that there is a world-wide interest in the subject, while a study of instrumentation indicates that the research workers are not confining themselves only to the light-meters being produced commercially but are in some cases devising new equipment for special tasks. In this connexion the paper by Evans (1956) is an important and interesting one.

RECENT DEVELOPMENT IN INSTRUMENTS

Although many interesting contributions on solar radiation were made by workers in the latter part of the nineteenth century, an examination of the literature on this subject shows that the greater part has been published since 1930; it is only since then that data have been obtained using instruments which may be called modern. Even at that time sensitized paper, used as far back as 1877, was still being used in photography and in light measurement: while the results may have proved interesting, such a method could not be regarded as a reliable one. The optical light meter was also used at one time in photography and could be employed to a limited extent in relative light measurement: in this instrument

the rotary adjustment of a small disk enabled the observer to determine the exposure for a given lens aperture. This instrument, although it had its severe limitations, could be employed in obtaining comparative measurements of the light intensity in the open and in forest stands of varying density, but it could not be regarded as an accurate instrument for this purpose.

The early instruments for measuring light intensity were followed by photo-electric cell photometers of varying efficiency which have been used up to the present time; those of today are more accurate than those of even a decade ago. It is not, however, intended to discuss the range of instruments and equipment which have been employed in the past, but to describe the methods of using some of the instruments which the writer is using in the field at the present time, including photometers, the more sensitive luxmeter, and the instrument known as the barrier-layer cell, which Dr. Connor has described in the previous paper.

PRESENT-DAY INSTRUMENTS

1. *The Photometer*

The reliable photo-electric cell photometer used by the photographer has its useful place in modern light intensity comparison; but it has its limitations. The ordinary photometer is relatively inexpensive, but it is only moderately sensitive to weak light intensities, and it is not easy to get a number, all of which will record the same measurements in a wide range of light intensities. Because of these factors, complicated methods are required, such as laboratory testing of the series to be used, careful adjustment and even inter-changing the photometers in the media in which the light intensity comparisons are being made, with rechecking of the instruments after use. Deterioration may set in quickly, requiring further adjustment or replacement of some of the portions of the photo-electric cell.

The photometer has its advantages, however, if highly accurate measurements of light intensity are not required and when preliminary comparative measurements only are being made. There is a number of small photometers on the market; interesting results can be obtained and useful data recorded, especially in regard to the comparison of light intensity in a number of different stand densities. The photometer is small, light, easily carried, and is readily used in the hand, so that no great preparations are necessary; a number may be used, so as to have a series in operation simultaneously, the number depending on the number of observers available: on the other hand, one observer may be able to record from a small number of instruments when readings are being taken in succession, at short intervals in a restricted area.

When two or more photometers are being used, it is desirable that they should record exactly on the zero mark when light is completely excluded; yet even if the photometers are adjusted so as to record zero, they may be found to vary in a wide range of light intensity. In order to ascertain the variation they should be tested in the laboratory against a constant light, their readings being recorded at regular distances from the source of light. In this way discrepancies can be recorded and corrections applied if necessary; this may be done by a correction factor or by plotting the results on a graph; if, however, expensive high class photometers

are used, it may be possible to have the series so adjusted that they record the same reading within the range of light intensity being measured.

It should be realized that the facility with which these photometers can be used and the ease with which assessments can be made are dangers in themselves. They should be used rather in preliminary examinations of light intensity as an aid to the use of more sensitive and accurate photo-electric cells such as the luxmeter and the siting of barrier-layer cells.

The photometer in the field. The ordinary small photometer can only be read when held in the hand; at more than arm's length it is impossible to read the scale accurately, so that the observer must evolve a standard method of holding the instrument. The best way is to mount it on either plywood or cardboard of foolscap size used for holding the book or paper on which the observations are to be recorded. The board should then be held at a constant height, the photometer being placed always at the same place on the board, preferably one of the top corners. When two or more observers are measuring light in different media at synchronized intervals, it is essential that they should face in the same direction, preferably due south, which should be determined by compass; observers of different build will cause a variation in the amount of light reaching the instrument. The board must be held horizontally so as to get the maximum overhead light.

Finally, there is the difficulty of the direct light in the open being too strong for the photometer to record and the needle being swung off the scale. This requires the use of a Kodak neutral filter which can be placed over the photometer window; varying densities of filters can be obtained, but in temperate regions densities of $\frac{1}{4}$ to $\frac{1}{20}$ are usually sufficient to enable readings to be recorded, even in bright sunshine; the use of filters is described later.

The photometer should be placed in a box with a good glass or perspex top, thus protecting the rather delicate photometer and allowing of its use even if there is intermittent rain. The box also protects the filter, which is ruined if any moisture falls on it, or if it is handled in any way: the filter is also more easily held in position over the photometer window; if the filter is used on the photometer without the help of the box then adhesive tape is required to fix it to the instrument, which is undesirable. Plate XII (Fig. 1), shows from left to right the photometer box with the filter in position, the photometer with filter, the luxmeter and its filter; the scale is 6 inches long.

When it is intended to assess the light intensity by photometer in different forest conditions compared with the full light in the open, it is essential to have one observer in each stand and one at the control in the open where the full light is recorded. Photometric readings should be made during the growing season, between 10 a.m. and 2 p.m. and during settled weather conditions, with little or no cloud. The readings must be taken at the same time, and are best made at predetermined intervals using synchronized watches; the intervals should not be less than 15 seconds. The interval depends on the conditions and the time available; it is much more important that a useful number of readings be taken; these should be at least 100 for each series. With a useful series of readings the arithmetical mean of the light measurement at the control may be taken as 100 per

cent.; the means of the light intensities in the forest stands can then be recorded as a percentage of the full light in the open. The variation in mean light in the different media can be shown graphically, by histograms or by diagrams in the form of a plan, if light measurements have been made at intervals throughout a given area; the graphical method was used by the writer in the measurement of light under sessile and pedunculate oaks (Fairbairn, 1954).

The methods of measuring light in a forest stand either by photometer or by luxmeter are described later.

2. *The Luxmeter*

The luxmeter (shown in Fig. 1) described by Roussel (1953) is a type of photo-electric cell which, because of its sensitivity, records light intensity with accuracy. It is larger than the photometer, it weighs approximately 2¾ pounds and the case measures 6 by 5½ by 3½ inches, yet it is easily portable and can be used in the hand, although it is not easy for the single observer to record instantaneous readings. The luxmeter has the advantage of having a 3-foot lead from the photo-electric cell to the scale, so that the cell can be used on the ground or at any convenient height from it, enabling the observer to read the scale without interfering with the light reaching the cell. It has the further advantage that it has three different degrees of sensitivity which are operated by a switch (providing different resistances to the current), so that strong, medium, or weak light intensities may be recorded; a neutral filter, which reduces the light intensity by one-twentieth, shown on the right in the photograph, can be used in strong sunlight. The disadvantages of this instrument are its high cost and the fact that it is less easily used by the single observer working on his own and who has to do his own recording. A similar type of instrument can now be obtained commercially in Britain.

As in the case of the photometers, the luxmeter should be checked in the laboratory, recording the light intensities at progressively greater distances from the source of light. This enables a check to be made so as to ensure there is no fault and that sensitivity has been maintained. If two or more luxmeters are used, they should be checked in the same way and then calibrated so that a correction between instruments may be made if necessary. If only one luxmeter is used in the field and the percentage of light in the open is to be determined at the same time, then a photometer may be employed at the control in the open: it is then necessary to calibrate the readings of the luxmeter and the photometer in the laboratory. After a series of measurements has been made in the field the two instruments should be rechecked.

The luxmeter in the field. The luxmeter can be used in the field very much in the same way as the photometer, but it has the merit of greater precision and when the cable between the cell and the scale is used, the observer in no way interferes with the light reaching the cell. As in the case of the photometer, instantaneous readings are made, whether the apparatus is set up at a fixed point or carried by the observer as he moves through a given area. In the former case the instrument is placed at a point in the stand in which light intensity values are required and the observer records the reading at suitable time intervals; these should not be less

than 15 seconds, and should number at least one hundred. In the case of measurements at a given point in a forest plot, the luxmeter can be used either at randomly chosen points or at the point which has been found to represent the average light intensity for a specific time of day as in (iv) below. The luxmeter, although it is less easily carried by the observer who is doing his own recording, can also be employed in traversing an area in which the light is to be measured. The procedure is the same for the luxmeter and for the photometer.

When the light intensity is measured in a forest stand, either by luxmeter or by photometer, using a control to ascertain the full light in the open, the following methods may be used:

(i) Points, which should be marked with pegs, may be taken at random; the readings are then taken in turn at these pegs and it is advisable to have at least 100 readings at each position. It is useful to restrict the number of points and the size of the plot so that the successive readings can be taken in successive positions at about 15 seconds' interval. Continuous readings of this kind should not be done for more than half an hour at a time by one person because of the rate of fatigue and resulting inaccuracy.

(ii) The light may be measured in a given plot at equidistant intervals along two diagonals which should run from the north-west and north-east corners of the area, so that the observer can face south while traversing the two lines the ends of which must be marked with stakes. The time or distance intervals for readings can be determined according to the conditions of the stand. In a square chain plot the intervals may be at one yard when each diagonal should be traversed five times to give over 100 readings on each. This method is not desirable as the light intensity is not measured in the triangles between the diagonals.

(iii) The four corners of the plot should be marked by stakes in the form of a square so that two sides run due north and south. Then taking the northern side as a base line, it is marked with numbered equidistant pegs at the interval at which it is intended to take readings; these must be duplicated as a guide on the southern boundary of the plot. The observer starting from the base line, on line one, takes readings at similar equidistant intervals, continuing to record on successive lines across the plot. In the case of a chain square plot the distance between the lines and between the points on the perpendicular lines might be two yards thus giving 121 readings for the plot. Two or three series of readings should be made in this size of plot. The mean of the percentage of full light in the open can then be recorded in the form of a diagram, for each two yards square in the square chain.

(iv) Using the previous method, and the arithmetic mean of the light intensity of the plot having been determined, that point or series of points at which that intensity has been recorded may be used for setting up luxmeters or barrier layer cells, when as long a series of measurements may be made as is found desirable, according to the objects of the light intensity measurement for the plot.

(v) Light intensity may also be measured on a transect or on a series of transects through a forest stand. This should run from north to south and may be from one chain to a number of chains in length depending on the object, the observer either

using a compass or setting out a series of stakes so that the line can be followed without requiring frequently to check the compass bearing; when measuring on a transect the measurements should be taken at about quarter chain intervals, again it is desirable to have at least 100 readings per transect. In each case it is useful to have the full light in the open measured at frequent intervals (preferably 15 seconds) so that the light intensity in the stand can be represented as a percentage of the light in the open; this must be done by a second worker whose readings should be plotted against synchronized time intervals so that the light intensity can be determined for any given time during the period in which the light measurements are being made, either in plots or on transects.

In each of the five methods great care should be taken to work in conditions of light as uniform as possible, choosing the day on which such conditions are present rather than carrying out the work on a predetermined day, no matter what conditions of cloud or weather obtain.

3. *The barrier-layer cell*

The barrier-layer cells and their technical details have already been described by Dr. Connor in the previous paper. The testing and use of the cells was evolved by Dr. Connor and the writer is grateful for his most valuable help.

The barrier-layer cells are shown in Plates XII and XIII (Figs. 2 to 4). In Fig. 2 the photo-electric cells in their perspex boxes are seen on the left and on the right; at the back is the box with the 'nest' for holding the voltameter while beneath the box lid is the tray for carrying the photo-electric cell. The voltameter containing the two silver plates and the silver nitrate solution is to the left of the six inch scale. Fig. 3 shows the barrier-layer equipment as used at the control in full light in the open at a forest nursery; on the left is the box, voltameter, and tray; in the centre two cells are seen with the trays into which they are fitted to keep them off the ground. Fig. 4 shows a close-up photograph of the voltameter with the two silver plates immersed in the silver nitrate solution. The beads of silver can be seen deposited on the silver plate on the left, a heavy deposition because of the cell being in full light for a period of two and a half months.

The barrier-layer cells in the field. The barrier-layer cells are, in some ways, the easiest equipment with which to work in the field; once the lengthy preparations are completed, including the accurate weighing of the silver plates, they are placed in the desired position and left for a predetermined period; this should not be less than two months, so as to get an appreciable deposition of silver, and should not exceed four months, after which there is the possibility of deterioration in the cells. In temperate regions the light intensity should be measured for the duration of the growing season; if the equipment is used thereafter, a separate series of measurements should be made.

The barrier-layer cell is the only one of the four recorded by Dr. Connor which provides a satisfactory method of cumulative light measurement over the chosen period, the amount of silver which is deposited being proportional to the amount of light reaching the cell. After having been calibrated the cells are used in the different media for the same period. One is placed in full light in the open

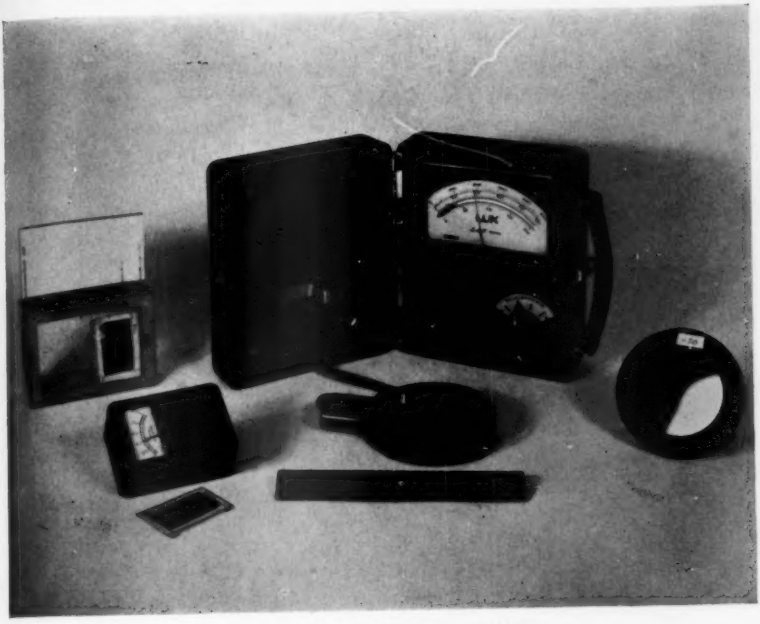


FIG. 1. Photometer, luxmeter, and filters

FIG. 2. Barrier-layer cell, box, voltameter, and cell-tray

W. A. FAIRBAIRN

PLATE XII

FIG. 3. Barrier-layer cell box, voltameter and two cells in the open

FIG. 4. Voltameter with silver plates showing deposition of silver, indicated by black arrow

W. A. FAIRBAIRN

PLATE XIII

and its weight of deposited silver is taken to represent the full light as 100 per cent., while the others indicate by the deposition of silver the percentage of light in the chosen media. There is the obvious limitation that no assessment can be made at present of the light value in units; this could be done mathematically for full possible light in the open without recourse to light measuring instruments, but is not within the realm of the practical or the realistic because of climatic and site variations.

It has been found that the deposition of silver crystals is slight when one cell only is used with the silver plate voltameter, even during two months in the open. It has therefore become normal practice to use two cells in the open and from two to as many as a battery of seven cells in forest stands; the cells should be sited at random. This number was used, for instance, in a one square chain plot, when results were obtained over a series of periods. When two or more cells are used, then it is necessary to divide the deposited weight of silver by the number of cells used: this has its obvious limitations, which are unavoidable at the present time. It is desirable when using say eight cells to have two sets of four and two voltameters.

FILTERS

It is generally found essential to use filters of one kind or another with the photometers and the luxmeter; in the case of the barrier-layer cells they are essential to protect the cell, being incorporated within the perspex box in each case. The neutral filter normally used with the luxmeter is one reducing the light intensity by $\frac{1}{20}$, and is shown in the photograph in Fig. 1. Others, however, may be used, including a green filter. The Kodak Wratten No. 34 green filter can most usefully be applied in forest sites, as the light frequencies which pass are near those which are absorbed by the chlorophyll structures, mostly the red and the blue portions of the spectrum. The filter used with each barrier-layer cell is tested in the laboratory in normal routine practice; all other filters should similarly be tested and variations recorded so as to determine the correction factor.

It has also been found desirable to use filters with the small photometers and essential when one is used as a control in full light in the open. It is desirable, although not essential, to use the same density of filter on the photometers used in the forest site, due allowance being made for the density.

A wide range of filter densities can be obtained, but it has been found that those of $\frac{1}{5}$, $\frac{1}{10}$, and $\frac{1}{20}$ density have been sufficient to date for all practical purposes. The filter is readily damaged; it is easily finger-marked and is spoiled if rain falls on it. It should be cut, avoiding touching it with the fingers, to the size required, such as that of the photometer window; the piece should then be placed between two pieces of clear film (preferably from a filter from which the emulsion has been removed), and using two narrow masks or frames of strong paper, the whole should be bound with adhesive tape, when the filter can be handled and used without difficulty. On occasion it is found that the light intensity in the forest stand does not suit the use of any one filter and that two are required to be used together so as to keep the needle on the scale at the maximum light intensity; a $\frac{1}{5}$ and a $\frac{1}{10}$

filters, for instance, might be used together. It is therefore useful to have a series of filters prepared so that they can be carried and handled easily in the field. Their use saves much time and enables measurements to be carried out under most conditions of light intensity which are normally met.

CONCLUSION AND ACKNOWLEDGEMENTS

A number, but not all, of the difficulties encountered in the measurement of light intensity in forest conditions seem to be at least partially solved, thanks to a number of workers. The modern luxmeter with its high accuracy in recording instantaneous light values, high class photometers, and the barrier-layer cell show great progress in the relative measurement of light under different forest media. Yet the instruments which continue to be evolved by research workers indicate that much has yet to be done in perfecting equipment; and no matter how efficient that equipment may be, there is always the challenge from the variations which occur in each forest stand, no matter how small they may be.

The writer records his thanks to those who have given permission to the Department of Forestry for light intensity measurements to be made in their woodlands; he is grateful to Dr. L. Roussel, of the Département des Eaux et Forêts in France, for much helpful advice and would especially thank Dr. R. D. Connor, B.Sc., Ph.D., of the Department of Natural Philosophy at the University of Edinburgh, for his invaluable assistance and co-operation.

LITERATURE REFERENCES

Evans, G. C. (1956): 'An Area Survey Method of Investigating the Distribution of Light Intensity in Woodlands, with Special Reference to Sunflecks.' *J. of Ecology*, xliv. 391–428.

Fairbairn, W. A. (1954): 'Preliminary Light-intensity Study under Sessile and Pedunculate Oak.' *Forestry*, xxvii. 1.

Roussel, L. (1953): 'Recherches théoriques et pratiques sur la répartition en quantité et en qualité de la lumière dans le milieu forestier, influence sur la végétation.' *Annales de l'École Nationale des Eaux et Forêts*, tome xiii, fascicule 2.

—— (1956): 'Sur quelques récentes études de photologie forestière.' *Revue Forestière Française*, No. 7.

THE STORAGE OF ACORNS IN WATER

By EUSTACE W. JONES

SUMMARY

Acorns of sessile oak (*Quercus petraea*) will not tolerate prolonged submergence, but those of pedunculate oak (*Quercus robur*) survive very well in regularly changed distilled water or tap-water. Survival is considerably worse in basic river water; the difference from tap-water is likely to be due either to the greater activity of organisms promoting decay, or to the prevalence of lower oxygen-tensions in river water. Storage in water under suitably controlled conditions might be a useful practical procedure with pedunculate acorns.

IT has frequently been claimed that acorns can be stored successfully by keeping them submerged in water; sometimes it has been specified that the water should be running. But the results which have been published of experiments with this procedure have been very diverse; some have shown it to be satisfactory, others, a complete failure. Palmer (1955) cites several of these results, and also carried out an experiment himself. In general there has been little to indicate the reasons for this varying success, though Schmidt (1931) found that acorns of pedunculate oak kept well in running water (70 per cent. germinated after storage) while those of sessile oak kept badly (16 per cent. germinated). Apart from this indication of a difference between the species which has usually been ignored, it may be deduced from experiments with other methods of storing acorns that the avoidance of anaerobic conditions would be essential.

On one occasion when I myself stored small batches of acorns under water, some at the bottom of a disused well, others in a bucket of tap-water, both stagnant, the cotyledons of the acorns remained plump and healthy but the radicle and plumule of the majority had decayed, so that they failed to produce plants when sown. Many of them nevertheless produced extensive adventitious root systems from the cotyledons during the course of two seasons, without making any aerial shoots; they might have continued to grow had they been given the opportunity. This decay of the radicle doubtless explains Burckhardt's comment (1880) that storage in water is suitable only for acorns which are to be used as winter feed for deer.

Palmer himself kept acorns of the two species in (*a*) unchanged tap-water, (*b*) tap-water which was changed weekly, (*c*) in a fast-flowing stream of calcareous water.

Acorns from different trees were kept separate. He confirmed the difference between sessile and pedunculate oak, but found that while almost all acorns, even of pedunculate oak, died in the unchanged water, the 'pedunculate' acorns in changed tap-water kept as well as did acorns sown in the autumn; survival in the stream was, however, considerably worse. The base-rich stream-water would doubtless encourage micro-organic activity and rapid decay, but it was also

suspected that the mere jostling of acorns against each other by the rapid current had injured them.

As acorns were abundant in the autumn of 1956 a further experiment was set up to obtain a little more information on the effects of different kinds of water. Acorns of the two species were stored in (*a*) distilled water, (*b*) tap-water, (*c*) river-water from the Cherwell, (*d*) 0·1 per cent. solution of copper sulphate in tap-water.

Sets of fifty acorns were kept in five to ten times their own volume of water in iron cans in an unheated greenhouse; in all treatments the water was changed weekly. All sets of fifty acorns of any one species were comparable in origin, being made up of equal numbers of acorns from either five trees of pedunculate oak or three trees of sessile oak. Sets of acorns were taken out of water and sown on 6th March, 18th March, and 2nd April. There were two replications (i.e. 100 acorns in all) of each treatment. Comparable sets of 100 acorns of each species were sown immediately in order to provide a figure for the germination of the fresh acorns; these acorns were germinated in artificial heat, so that they do not provide a figure for the percentage of plants which would have been obtained from acorns kept in the ground over winter. The results are presented in the accompanying table.

Unfortunately mice, which were exceptionally troublesome in the spring of 1957, found their way to the experimental sowings and removed some of the acorns from three groups of pedunculate oak sown on 6th March; thus in the statistical analysis of variance either the figures for this sowing must be ignored, or estimates of the germination of the missing acorns must be used in place of the vitiated figures. This latter procedure is of course not strictly valid, and the only difference which it makes is to increase the significance of the interaction of species × method, and to render significant the variation due to length of storage and the interaction, species × length and of method × length of storage.

Copper sulphate solution was used because it is a fungicide which, if effective, could easily be used on a large scale. While the acorns kept in it remained sterile enough, the majority, as the figures show, were killed; possibly some lower concentration might not be harmful.

The figures confirm the great difference between sessile and pedunculate oak in their tolerance of submergence; this difference is in keeping with the preference of pedunculate oak for heavy wet soils and its common occurrence in riverain woodland, including sites which are liable to flooding in winter. The water in which sessile acorns were kept became dark brown, and tests with ferric chloride and lead acetate showed that it contained abundant tannins; the water from pedunculate acorns remained pale and contained no tannins. The figures also confirm that river water is markedly poorer as a storage-medium than tap water; moreover, the difference is remarkably close to that found by Palmer (taking the average of his figures for 'germinated' and 'ungerminated' acorns, sessile oak in tap-water 22·4 per cent., in river-water 13·4 per cent.; pedunculate acorns in tap-water 75·8 per cent. in river-water 59 per cent.; ratio of the two, sessile oak, approximately 1·7, pedunculate oak 1·3; ratios in the present experiment 2·2 and 1·3 respectively). The mechanical action of a swift current was here excluded,

Percentage of acorns surviving storage in four kinds of water

Length of storage	*Method of storage*				
	(a) Distilled water	*(b) Tap-water*	*(c) River-water*	*(d) 0·1 per cent. copper sulphate*	*Percentage germination excluding (d)*
Sessile oak:					
Sown in Autumn	..	..	..	..	85
Sown 6th March	33	34	14	2	27
Sown 18th March	24	27	12	1	21
Sown 2nd April	18	12	7	1	12·3
Total (out of 300)	75	73	33	4	..
Total per cent.	25	24·3	11	1·3	..
Pedunculate oak:					
Sown in Autumn	..	..	..	..	97
Sown 6th March	30*	65	30*	11*	62·5
Sown 18th March	65	58	51	14	58
Sown 2 April	59	59	32	13	50
Total (out of 300 or 250*)	154	182	113	38	..
Total per cent.	60·2	60·7	45·2	15·2	..

* Out of 50 acorns (one replication) only; the second replication having been partly destroyed by mice. All other figures are numbers germinating out of 100 acorns (two replications).

Analysis of variance of sowings on 18th March and 2nd April

Origin of variation	*Degrees of freedom*	*Sum of squares*	*Mean square*	*Significance*
Between species	1	1,984·5	1,984·5	0·1%
Between methods	3	1,519·75	506·58	0·1%
Between lengths of storage	1	91·125	91·125	nearly 5%
Interaction of:				
Species × method	3	296·25	89·75	5%
Species × length	1	0·085	..	..
Method × length	3	33·625	..	..
Error	19	465·665	24·51	..

Standard error based on preceding analysis of variance of difference between methods of storage of a single species, 4·95 acorns per 100; for the two species together, 3·5 per 100.

Standard error of difference between lengths of storage for each species, 3·5 acorns per 100; for the two species together, 2·45 per 100.

so that the harmful effect of river-water must be due either to its encouragement of micro-organisms or to a low oxygen tension resulting from the oxidation of organic matter in the water. The Oxford tap-water used in both Palmer's and my own experiment is hard. The Cherwell resembles the stream used by Palmer in being highly basic, but differs in being a slow stream carrying much more sediment. Oxford tap-water is drawn from the River Thames, and probably

therefore differs little from Cherwell water except in the absence of suspended matter and of some excess carbonate, and in having been chlorinated; it has been as good a storage medium as distilled water.

The deterioration of sessile acorns during the course of March is appreciable. It is, however, doubtful to what extent the pedunculate acorns have deteriorated during this period; the figures suggest that possibly only in river water have they deteriorated appreciably.

The winter of 1956–7 was exceptionally mild, with no prolonged cold and very little frost, even at night; moreover, temperatures during the day in the sunny greenhouse where the acorns were kept must have been appreciably higher than temperatures in the open. Thus conditions for storage were less favourable than they might easily have been, and the average germination of 76 per cent. found by Palmer for pedunculate acorns in tap-water changed weekly is probably a better indication of what can be expected from storage under water than is the 60 per cent. germination of acorns in the present experiment. It may be concluded that while storage under water is quite impracticable for sessile acorns, it may provide a method of keeping pedunculate acorns which is no more troublesome and at least as effective as the usual method of storing in thin layers in special sheds.

LITERATURE REFERENCES

Burckhardt, H. (1880): *Säen und Pflanzen nach forstlicher Praxis*, 5th ed., Trier.

Palmer, S. R. (1955): 'A Comparative Experiment in the Storage of Acorns of *Quercus pedunculata* and *Q. sessiliflora* under water.' *J.O.U. Forest Soc.*, 4th ser., no. 3, 14–25.

Schmidt, W. (1931): 'Zur Wirtschaftlichkeit der Lagerungstechnik von Laubholzsamen.' *Deutsche Forstwirt*, xiii. 562–5.

MOISTURE AND TEMPERATURE CONDITIONS IN AFFORESTED AREAS IN ABERDEENSHIRE

By J. R. H. COUTTS

(*Department of Soil Science, University of Aberdeen*)

SUMMARY

1. Soil temperature measurements in a forestry plantation at Birkhall, near Ballater, Aberdeenshire, have been maintained from January 1952 onwards, and the present paper extends the results already published (*Quart. J. Roy. Met. Soc.* lxxxi (1955), 72) with regard to soil temperature profiles, frost occurrence, and the efficiency of daily maxima and minima of temperature in the estimation of mean weekly temperatures.

2. Results are given for the interception of rain by vegetational covers of various types and for the differences in moisture status that occur between soils in an open ride and under the forest canopy.

3. The amplitudes of diurnal temperature fluctuations in the ride and under the forest canopy have been compared. Over the period August 1954 to December 1956, the latter average about 60 per cent. of the former; there are, however, large differences between the results for the dry conditions in 1955 and the wet conditions in the later months of 1956, and consideration is given to the factors contributing to these differences.

4. The mean temperatures in the ride are higher than those under the canopy between April and September; the greatest differences, which are of the order of 1° C., occur in the later part of the spring and the earlier part of the winter.

INTRODUCTION

IN a paper presented at the Edinburgh meeting of the Royal Meteorological Society in July 1954 the present writer (Coutts, 1955) gave an account of the results obtained during the first two years of an investigation undertaken in the Alltcailleach Forest, Birkhall, Aberdeenshire, in order to obtain quantitative data on the effects of a forest cover in moderating the influence of air temperature fluctuations upon conditions in the soil. The present paper includes an account of further work carried out at the same and neighbouring sites in the years 1954–6, and continuing into 1957.

SITES

In the course of the earlier work, it was noted that the diurnal temperature fluctuations at depths of 12 inches and 18 inches were small and that no frost penetration had extended to these depths in the winters of 1951, 1952, and 1953. It was decided, therefore, to re-site the four available mercury-in-steel recording thermometers, placing two of them in the centre of the ride at depths of 1 inch and 6 inches, and the other two at the same depths near the third row of trees, i.e. about 12 feet within the forest plantation. In consequence of this change, estimates of mean annual soil temperatures quoted below for the year 1954 have been made by combining readings obtained at the old site for the period January to July with those obtained at the new site for the remainder of the year.

Rainfall interception data discussed below have been obtained from Cambus

O'May, with the neighbouring area of Dinnet, and from Glentanar. These districts lie in the Dee valley and east of Birkhall, which is approximately 6 miles from Cambus O'May and 10 miles from Glentanar; climatic conditions are similar at all these sites.

RAINFALL INTERCEPTION BY VEGETATION

Rainfall records for 1954, 1955, and 1956 derived from a rain-gauge with normal exposure at Birkhall are shown as cumulative graphs in Fig. 1. For the period 1952 to 1956, the highest rainfall occurred in 1954, and the lowest in 1955. While the

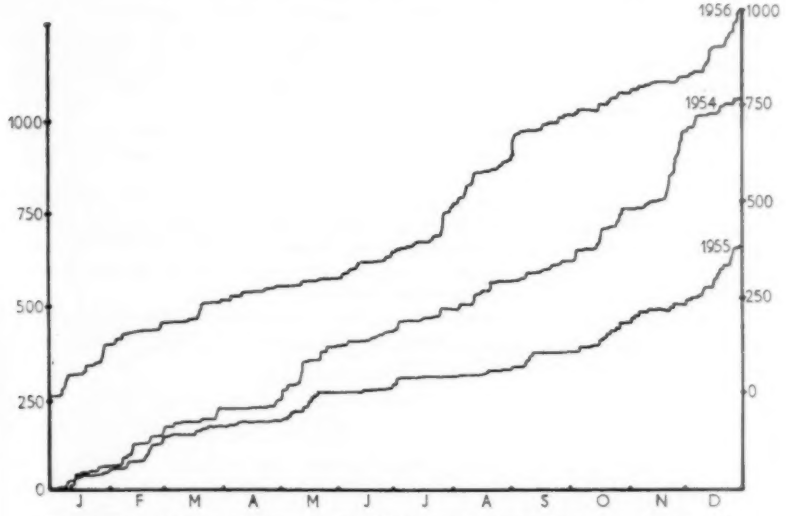


FIG. 1. Cumulative rainfall graphs. Rainfall in mm. Ordinates for 1954 and 1955 on the left; for 1956 on the right.

figures show that the wettest period has varied in its incidence from year to year, it is of interest to note that in each year the period of minimum rainfall has been in the spring, between March and May.

The nature of the vegetational cover plays a vital role in determining the proportion of the actual rainfall that reaches the soil. According to Ovington (1954), the amount of interception by a forest canopy may vary from 6 per cent. to 93 per cent., the highest values occurring when the precipitations fall as light showers and a large proportion of the water is retained by the foliage. For trees with a horizontal branching system, Ovington found that the run-off from the trunks is usually small. Pozdnyakov (1956) obtained results illustrating the reduced interception by birch as compared with pine, and Bodeux (1954) observed cases in which the interceptions by pine, oak, and heather were about equal (27 per cent.).

As there are no records of rainfall interception at Alltcailleach Forest, data collected by Stewart (1956) at Cambus O'May, Dinnet, and Glentanar are given

in Table I. The two sets of conditions at these sites that approximate most nearly to those found at Alltcailleach Forest are (1) the closed canopy of pine under which there is no ground vegetation, and (2) the heath at Glentanar, where the growth of heather is not as dense as at Dinnet Moor. Stewart's observations were

TABLE I. *Percentages of rainfall penetrating various types of vegetation*

Site	*Glentanar*					*Cambus O'May and Dinnet*				
Vegetation:										
Canopy	O	P	P	P	P	O	B	B	B	P
Ground	H	H	G	M	O	H	H	G	M	O
Period ending 1956:										
31 Mar.	62	101	74	100	38	..	..	..	..	..
3 May	59	83	83	63	25	40	82	76	62	35
6 June	54	65	43	43	30	35	89	62	69	53
6 July	64	70	65	63	21	27	84	72	64	38
13 Oct.	..	..	..	..	..	45	86	82	68	10
11 Nov.	38	67	43	42	15	20	91	80	78	54

O = none; H = heather; G = grass; M = moss; P = pine; B = birch.

made under pine (*Pinus sylvestris*), under birch (*Betula alba*), and on moors of heather (*Calluna vulgaris*). The densities of the tree canopies at different forest sites are indicated by the nature of the ground vegetation. Since it was the purpose of the investigation to estimate the rainfall interception by the canopy, the gauges were placed above the ground vegetation (if any), while on the heaths they were placed at ground level, screened by the growth of heather.

The large measure of interception by the closest forest canopy (under which there is no ground vegetation) is obvious in Table I. There is also some indication of increasing interception in the heather–grass–moss sequence of undergrowth, but the trend here is less marked, and some of the higher values recorded for penetration in the Table must be ascribed to dripping from the foliage.

SOIL MOISTURE

The moisture status of the soil must be appreciably affected by the interception of rainfall by the vegetative cover, but other climatic factors must also be taken into account in comparing conditions under a canopy and under a bare surface. These include differences in atmospheric temperature and humidity and in air movements (leading to differences in evapotranspiration), and, in winter, in the depth of frost penetration, and in the rate of thawing. The net effect of the interactions of these factors under the conditions prevailing at Alltcailleach Forest appears to be that, except in the driest periods, the soil moisture content under the canopy is lower than that in the ride. Typical results are shown in Table II.

EFFICIENCY OF SPOT READINGS

In the earlier paper (Coutts, 1955), it was shown that the average values of daily maximum and minimum temperatures led to estimates of weekly mean temperatures that were reasonably accurate in the case of soil temperatures but,

as might be expected, the deviations between true and estimated weekly mean air temperatures were considerably greater. The distributions of the deviations (regardless of sign) for the whole of the period 1952 to 1956 are summarized in Table III and confirm the conclusions drawn from the 1952 to 1953 results.

TABLE II. *Soil moisture at Alltcailleach Forest: Percentage of 2 mm. sieved soil dried at 105° C.*

		Depth (inches)			
		In ride		*Under canopy*	
		0–1	*1–6*	*0–1*	*1–6*
1954	9 Sept. . . .	314	135	52	44
1955	31 Jan. . . .	96	69	71	51
	8 May . . .	126	57	68	45
	20 July . . .	27	20	83	22
	4 Dec. . . .	63	44	53	30
1956	7 Jan. . . .	75	..	54	46
	6 May . . .	93	59	43	39
	11 July . . .	49	26	92	30
	18 Aug. . . .	157	43	149	58
	13 Oct. . . .	39	45	110	45
1957	7 Jan. . . .	71	51	58	46

TABLE III. *Deviations from true weekly means of means estimated from daily maxima and minima. Percentages of numbers of observations*

	Deviations (° C)										
	0–0·5	*0·5–1·0*	*1·0–1·5*	*1·5–2·0*	*2+*		*0–0·2*	*0·2–0·3*	*0·3–0·5*	*0·5–1·0*	*1+*
Air	69·4	19·1	7·2	2·6	1·7	Soil:					
						1 in.	77·1	10·4	8·5	3·7	0·3
						6 in.	88·6	7·7	3·7	..	..

The estimated soil temperatures are usually slightly lower (by about 0·1° C.) than the true means, but the estimated air temperatures are nearly always too high. This latter observation is in contrast with Kew data, quoted by Macfadyen (1956), which showed that the estimated temperatures were too high in winter, but slightly too low in summer. The difference between the two sets of results may be due to the fact that at the site in the forest ride there is partial shading of the sun at low altitudes by the neighbouring trees, so that temperatures near the maxima persist for shorter times than with full exposure, and temperatures near the minima remain steady for longer than under normal conditions.

TEMPERATURE DATA

Mean, maximum, and minimum temperatures are shown in Table IV. As mentioned earlier, the soil temperatures for 1954 are composite weighted means from two similar sites. It will be seen that the differences between the annual

means from year to year are small: the higher maxima for the abnormally warm summer of 1955 are counterbalanced by the low minima for the hard winter of 1954–5, and the mean soil temperatures for 1955 are in fact about 1° C. lower than those obtained in 1953 (Coutts, 1955, Table 3). Inspection of the absolute minima gives some indication of the screening effects of the soil layer and of the

TABLE IV. *Absolute maxima, minima, and mean temperatures (° C.), in air and in soil, Alltcailleach Forest*

			Soil			
			In ride		*Under canopy*	
			Depth (inches)			
		Air	*1*	*6*	*1*	*6*
1954	Max. . .	24·6	17·8	13·2	12·1	11·2
	Min. . .	−13·1	−1·4	0·0	1·0	1·2
	Mean .	6·2	..	..	5·6	5·8
1955	Max. . .	30·1	17·3	14·4	16·3	14·6
	Min. . .	−15·3	−1·2	0·3	−1·0	0·1
	Mean .	5·4	5·5	5·9	5·5	5·7
1956	Max. . .	24·4	16·3	12·9	12·9	11·0
	Min. . .	−13·4	−0·7	0·5	−0·3	0·2
	Mean .	5·6	5·5	5·8	5·2	5·5
Means:						
1952–6	Max. . .	30·1	17·3*	14·4*	16·3	14·6
	Min. . .	−15·3	−1·2*	0·3*	−1·7	0·0
	Mean .	5·8	5·5*	5·9*	5·8	6·0

* 1955–6 only.

forest canopy against frost, and the ranges between maxima and minima show that the amplitudes of the annual variations are appreciably affected by the forest canopy. These two matters are discussed below in rather greater detail.

FROST OCCURRENCE

Table V shows the monthly distribution of frost days in the air and in the soil at a depth of 1 inch. At the old site, frost temperatures were recorded at a depth of 6 inches on 9 occasions in 1952, 3 in 1953, and 2 in 1954, but none has been recorded at the new site. In the mild period at the end of 1954, no frosting occurred at a depth of 1 inch and the figures shown for the first part of the year are for the old site. It is evident from the data in this Table that frost occurrences are most frequent in the months January, February, and March, and that in the winter seasons frosting to a depth of 1 inch is unusual before December. With regard to the air data, it should be recalled that these refer to the readings in a Stevenson screen, 4 feet above ground level, and that the temperatures given by

a grass minimum thermometer are lower than the air minima quoted above; grass minima of 0° C. or lower were recorded at least once every month throughout the period 1952–6.

The durations of frost-free periods are summarized in Table VI. Although the severity of the winters has varied considerably in the course of the observations, the periods of frost risk have shown relatively small differences: it appears that

TABLE V. *Number of frost days in Alltcailleach Forest, in air and at depth of 1 inch in ride and under canopy*

		Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June–Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Yearly total*
1954 . .	A	17	22	12	20	0	0	2	5	10	13	101
	C	12	25	20	0	0	0	0	0	0	0	57
1955 . .	A	20	24	27	10	11	0	0	10	6	18	126
	R	17	24	31	3	0	0	0	0	0	7	82
	C	15	16	16	0	0	0	0	0	0	6	53
1956 . .	A	22	25	21	24	2	0	2	1	9	9	115
	R	5	22	17	0	0	0	0	0	0	0	44
	C	1	19	6	0	0	0	0	0	0	0	26
Means:												
1952–6 . .	A	19·4	20·2	18·2	14·4	3·4	0	0·8	3·8	8·2	13·4	101·8
1955–6 . .	R	11·0	23·0	24·0	1·5	0	0	0	0	0	3·5	63·0
1952–6 . .	C	13·2	17·6	9·8	0·2	0	0	0	0	1·4	6·8	49·0

A = air in Stevenson screen; R = soil at depth 1 inch in ride;
C = soil at depth 1 inch under canopy.

TABLE VI. *Frost-free periods, Alltcailleach Forest*

Air	*Soil (depth 1 inch)*	
	In ride	*Under canopy*
1952 8 May–1952 11 Oct.	..	1952 17 Mar.–1952 24 Nov.
1953 8 May–1953 12 Nov.	..	1953 4 Apr.–1954 1 Jan.
1954 1 May–1954 7 Oct.	1954 19 Mar.–1955 12 Jan.	1954 19 Mar.–1955 11 Jan.
1955 29 May–1955 4 Oct.	1955 3 Apr.–1955 21 Dec.	1955 30 Mar.–1955 20 Dec.
1956 20 May–1956 16 Sept.	1956 21 Mar.–1957 18 Jan.	1956 8 Mar.–1957 20 Feb.

from the end of May to mid-September and from the beginning of April to mid-December can be taken as good approximations for the frost-free periods in air and at a depth of 1 inch below the soil surface respectively.

It will be seen from Tables V and VI that the frequency of frosting in the ride is significantly greater than that under the forest canopy, but that the differences between the dates of termination of the frost-prone periods in these two positions are only slight. In the coldest periods, cases have been found in which the frost persists longer under the trees than in the ride, but such cases are rare. Comparing

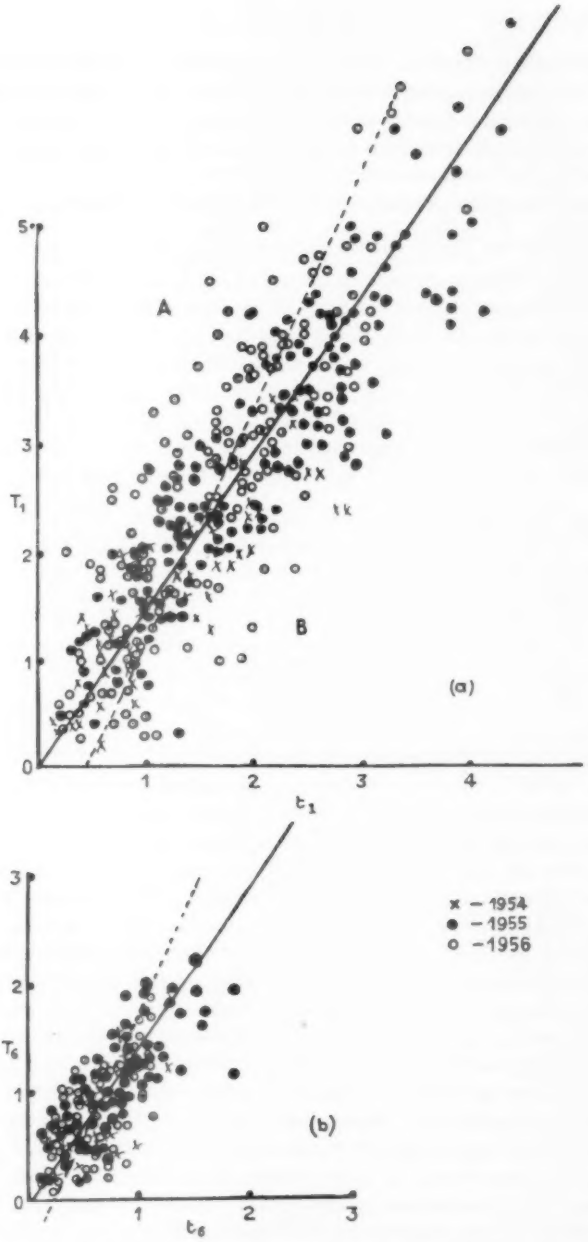


FIG. 2. Temperature amplitudes in soils in ride and under canopy; (*a*) at depth 1 inch, (*b*) at depth 6 inches. Least mean square lines: 1955, continuous; 1956, broken.

winter conditions in the forest with those in the ride, it may be noted that in the forest (1) the minimum (and mean) temperatures are higher, (2) the thermal capacity of the soil is lower, on account of the lower moisture content (see Table II), (3) the amount of snow-melt is smaller, and (4) the surface is less exposed to cold winds. In most cases, the effects of these factors more than counter-balanced the tendency due to direct insolation towards more rapid thawing in the ride.

EFFECT OF CANOPY UPON DIURNAL TEMPERATURE FLUCTUATIONS

The shading effect of the forest canopy in frost-free periods can conveniently be discussed in terms of the amplitudes of the diurnal temperature fluctuations. In Fig. 2, the amplitudes in the ride at depths of 1 inch and 6 inches (T_1 and T_6) are plotted against the corresponding amplitudes under the canopy (t_1 and t_6) for all available data from August 1954 to December 1956. Linear relationships have been fitted to the data by calculating the parameters for the least mean square lines, and these are summarized in Table VII. For each period, the slopes of the lines for the 1-inch and the 6-inch strata are roughly the same; the largest

TABLE VII. *Parameters of least mean square lines* $t = mT + c$ *from* n *observations of temperature amplitudes, Alltcailleach Forest*

	(T_1, t_1)			(T_6, t_6)		
	n	c	m	n	c	m
1954 .	84	−0·029	0·830±0·049	71	0·108	0·700±0·075
1955 .	202	0·054	0·685±0·054	179	0·028	0·713±0·031
1956 .	217	0·371	0·487±0·068	174	0·181	0·486±0·033
1954–6	503	0·236	0·593±0·015	424	0·109	0·619±0·027

difference occurs in the lines for 1954, for which year readings are available for the period August to December only. Averaging for the whole period 1954–6, the results show that amplitudes in the forest are about 60 per cent. of those in the ride, but there are surprisingly large differences between the results for 1955 and 1956, which give values of approximately 70 per cent. and 50 per cent. respectively.

Of the physical conditions that contribute to the scatter of the points about the least mean square lines, the following are probably the most important: (1) changes in moisture status, which lead to changes in thermal capacity and in diffusivity, (2) superposition of a slow steady trend in temperature on the diurnal variations at one of the two sites, as may occur at the onset of a warm period or a cold period. Many of the largest deviations for the 1956 data in Fig. 2 can be explained in terms of these features. For example, in the group of points near A in the figure the observed values of t_1 are significantly lower than the calculated values, and in the region near B the observed values are too high. Most of the points near A refer to readings in the spring, when the moisture content of the humus layer under the trees was unusually low; as can be seen from Table II, on 6th May this moisture was almost equal to that in the underlying mineral soil and was probably well below the field capacity for a humose soil. Under these conditions, the surface layer and litter would act in the same way as a dust mulch and

reduce the temperature changes at a depth of 1 inch. On 13th October moisture conditions in the ride were similar to those applying under the canopy in May, and the tendency would therefore be for a reduction of the temperature fluctuations in the ride relative to those occurring in the forest: points in the region B illustrate this case.

There is, however, a further factor to be taken into consideration with regard to the abnormally low temperature fluctuations in the ride in autumn or early winter. As already stated, there was no frosting at a depth of 1 inch in this period in 1956, but ground frosts occurred and these would be more frequent in the ride than under the protection of the canopy. Thus, at the exposed surface, and in any part of the top inch of soil affected by frost, a greater proportion of the energy received during the short daily periods of insolation would be expended in bringing about the phase change from ice to water. This feature may provide an explanation for cases in winter when the amplitudes in the ride are equal to, or even smaller than, those in the forest. In the limiting case, when the soil in the ride is frozen to a depth of 1 inch, while the top inch of the forest soil is not completely frozen, we should have $\mathcal{T}_1 = 0$ associated with a small finite value of t_1.

If soil conditions, particularly as regards moisture status, and environmental conditions such as vegetational cover varied comparably at the two sites, then (under frost-free conditions) the constant c in the equations for the least mean square lines should not differ significantly from zero. Referring to Table VII, it will be seen that this result is applicable to the periods 1954 and 1955, with the possible exception of the 6-inch figure for 1954. But for 1956 the c's are much larger than can be accounted for by random errors. It may well be that the disturbing factors mentioned above render it unjustifiable to attempt to fit a single straight line to the data for the year 1956 when the spring was very dry and the latter part of the year very wet. It would, of course, be possible to draw two straight lines, one of which would give a good fit for points biased towards A (Fig. 2), and the other for points biased towards B; but this has not been done, as the multiplicity of factors involved makes it impossible to find an objective method for allocating points to the respective groups.

EFFECT OF CANOPY UPON SEASONAL TEMPERATURE DIFFERENCES

As seen in Table IV, the mean annual temperatures at the positions in the ride and under the canopy differ only by negligible amounts. There is, however, a marked seasonal effect observable in the temperature differences between the two sites and at each of the two depths. Although the two years 1955 and 1956 were subject to widely dissimilar conditions of air temperature and of soil moisture, the results shown in Table VIII indicate that in each of these periods the soil temperatures in the ride were higher than those in the forest from the beginning of April to mid-September. The largest excesses of temperature in the ride occurred in May or June, and the largest deficiencies between November and January. It will be noticed that the transitions between excesses and deficiencies of the temperatures in the ride occur at approximately the same times as those at which temperature inversions occur in the soil profile, and that the largest values

of these differences occur when the mean temperatures were either rising to their summer maxima or falling to their winter minima.

TABLE VIII. *Temperature differences between sites in ride and under canopy, Alltcailleach Forest: (T—t)° C., weighted monthly means*

Depth:	*1 inch*			*6 inches*		
Difference:	*Mean*	*Max.*	(*Date*)	*Mean*	*Max.*	(*Date*)
1954 Sept.–1955 Apr. .	−0·5	−0·8	(Dec.)	−0·4	−0·8	(Nov.)
1955 Apr.–1955 Sept. .	+0·9	+1·5	(May)	+1·2	+1·7	(May)
1955 Sept.–1956 Mar. .	−0·7	−1·3	(Nov.)	−0·6	−1·2	(Nov.)
1956 Apr.–1956 Sept. .	+1·2	+2·1	(June)	+1·2	+2·1	(June)
1956 Sept.–1957 Mar. .	−0·9	−1·1	(Jan.)	−0·7	−0·9	(Nov. to Jan.)

ACKNOWLEDGEMENTS

I wish to thank Dr. D. J. Finney for his advice on appropriate methods for the treatment of the data summarized in Table VII. Mr. V. I. Stewart has provided me with his unpublished data on rainfall interception, and has given valuable assistance in drafting the section dealing with this topic The diagrams have been prepared by Mr. Brian Bruce. The Forestry Commission, through their Conservator Mr. F. Oliver, have given continued permission to operate the instruments on land in their occupation, and Mr. D. Marnoch, the forester at Alltcailleach, has now maintained the daily and weekly records for more than five years.

LITERATURE REFERENCES

Bodeux, A. (1954): 'Recherches écologiques sur le bilan d'eau sous la forêt et la lande de Haut-Campire.' *Agricultura Louvain*, ii. 47.

Coutts, J. R. H. (1955): 'Soil Temperatures in an Afforested Area in Aberdeenshire.' *Quart. J. Roy. Met. Soc.* lxxxi. 72.

Macfadyen, A. (1956): 'The Use of a Temperature Integrator in the Study of Soil Temperature.' *Oikos*, vii. 56.

Ovington, J. D. (1954): 'A Comparison of Rainfall in Different Woodlands.' *Forestry*, xxvii. 41.

Pozdnyakov, L. K. (1956): 'The Role of Rain Penetrating Beneath the Forest Canopy in the Process of the Exchange of Material between Forest and Soil.' *Soils and Fert.* xix, abstr. 1820.

Stewart, V. I. (1956): Private communication.

THE FIRST INTERNATIONAL SYMPOSIUM ON TREE PHYSIOLOGY

By S. D. RICHARDSON

(*Department of Forestry, University of Aberdeen*)

SUMMARY

The author considers briefly the main points made by speakers at Harvard University in April 1957 under the discussion headings, Water Relations and Sap Movement; Photosynthesis; General Biochemistry; Mineral Nutrition; Phloem Transport; Root Growth; Other Growth Phenomena; Photoperiodism and Thermoperiodism; and Reproduction. He remarks on the serious gaps in our knowledge of tree physiology revealed by the discussion and regrets that professional foresters should have been so thinly represented at the symposium.

FOR a long time, foresters in all parts of the world have been more interested in how to grow trees than in how trees grow. Forestry research has been almost entirely *ad hoc*, and it is only in recent years that the adequacy of the empirical approach has been seriously questioned. As forestry becomes more intensive, however, it is being increasingly realized, both on the continent of Europe and in North America, that many of the problems of tree growth which confront us are essentially problems in physiology; close co-operation between the forester and the physiologist is long overdue and could be of considerable mutual advantage. One outcome of this realization in the United States has been the symposium on tree physiology sponsored by the Cabot Foundation for Botanical Research at Harvard University in April 1957. Because it was the first gathering of its kind ever to be held, and since it was generally agreed (at any rate by the participants) that it served an extremely useful purpose, a report on the meeting may be of interest.

The symposium was held at the Harvard forest from 8th to 12th April and was attended by 30 invited speakers from the following countries: U.S.A., Canada, Germany, Norway, New Zealand, and Great Britain. Most of the participants are active in the field of tree physiological research and the wide range of their interests is illustrated by the following list of session titles, under which papers were presented and discussed:

Water Relations and Sap Movement (6 papers)
Photosynthesis (3 papers)
General Biochemistry (3 papers)
Mineral Nutrition (2 papers)
Phloem Transport (3 papers)
Root Growth (4 papers)
Other Growth Phenomena (5 papers)
Photoperiodism and Thermoperiodism (4 papers)
Reproduction (5 papers)

Most of the papers were of a high standard and they have been published, together with the discussions following each, in book form.* Since, however, this publication may not be readily accessible to readers in Britain, a brief account of the research reported may not be superfluous.

A whole day was devoted to the first of the above topics, beginning with a re-examination of the cohesion theory of the ascent of sap by the Norwegian zoologist Scholander. He reported studies of hydraulic conditions in grape vines and lianas, demonstrating that before leaf opening in spring the sap pressure shows a normal hydrostatic gradient; such a gradient has not been demonstrated, however, during transpiration. Partially severing a transpiring vine results in a marked lowering of the pressure above the cut, but the air taken in is confined to the severed elements and does not spread laterally. Although the pressure above the cut may reach cohesive values, the vessels of excised twigs appear to cavitate when put under tension and this fact provides a serious obstacle to experimental demonstration of the cohesion theory, as does the evidence presented by the Canadian workers, Greenidge and Gibbs, of extensive lateral water movement in stems. Greenidge reported that treatments such as mechanical interruption of vessels, defoliation, and the removal of a stem from its root system exercised relatively little influence on the pattern and rate of water movement in the stem, while Gibbs was concerned primarily with the diagnostic value of specific differences in water movement patterns. The evidence of Gibbs, however, suggested that observed differences in the pattern of moisture distribution in stems may be due to differences in time of the spring rise of sap rather than to differences in the pattern of movement.

Taking the data of these three papers together with those of Marvin (U.S.A.) on the physiology of maple sap flow, the conclusion seems to be justified that movement through the xylem is due primarily to physical forces, but that the initiation of movement is determined biologically. The precise mechanisms involved—both physical and biological—remain as obscure as when Dixon (1914) and Jolly performed their famous experiments; we still do not know how or why sap rises.

A discussion by Bollard (New Zealand) of the biochemistry of nitrogenous compounds in tree xylem sap and a paper by Stone (U.S.A.) on dew absorption by conifers completed the first session. Stone presented convincing evidence that dew may considerably prolong the survival of coniferous seedlings growing in soil at the so-called 'ultimate wilting point' and that even after the death of the root system the shoot may remain alive. During the discussion following his paper, evidence of water movement from plant roots into the soil was presented and the suggestion made that water and nutrients added to part of a root system can be transferred to dry soil surrounding an isolated portion of the same root system. In conclusion, the difficulty of deciding when a pine seedling is dead or alive was stressed, providing a striking example of how little we know of the physiology of tree seedlings.

* *The Physiology of Forest Trees*, edited by Kenneth V. Thimann, 1958. The Ronald Press Co. New York. pp. 678. 226 illustrations and 66 tables. Price 12$.

The session devoted to Photosynthesis was introduced by Kramer (U.S.A.), a man who has done more than anyone to stimulate an interest in tree physiology among foresters. Following his review of the environmental factors influencing photosynthesis, the German forester Huber—a pupil of Münch and the successor of von Molisch—described his method of measuring gas exchange under field conditions. By means of an infra-red gas analyser, Huber measures the carbon dioxide and water vapour content of the air at different levels above a continuous vegetation cover. Results to date demonstrate that the CO_2 content of the air is maximal just before sunrise and minimal in the afternoon. These variations, however, are not entirely due to changes in photosynthesis but are affected by vertical air movement which is intensified after sunrise. So far, Huber has not applied his technique to a forest stand and the results of such an application will be awaited with interest. Since CO_2 is often the factor which limits photosynthesis under field conditions and since, further, it is to be expected that turbulence in a forest stand would be less than over a cereal crop, such measurements may be expected to confirm previous suggestions of greater efficiency in trees than in other crops.

To close this session, one of Kramer's students, Bormann, described a study of photosynthesis rates in seedlings of *Pinus taeda*. His finding that primary needles are photosynthetically more efficient than secondary needles but are light-saturated at lower intensities confirms work of the present writer with deciduous tree seedlings (Richardson, 1957); though it was agreed that further work will be necessary to substantiate either Bormann's explanation of these phenomena on morphological and anatomical bases, or the writer's contention that changes during maturation are primarily physiological. Perhaps the most valuable feature of this session was the illustration given by Kramer of the way in which physiological experimentation can enable foresters and ecologists to understand certain of their empirically derived practices and observations. In eastern America, one of the major problems facing the forester is how to maintain stands of pine against the invasion of unwanted hardwoods; under canopy, hardwood seedlings thrive while the pines fail, and argument concerning the relative importance of light and moisture in creating this situation has raged among foresters since Fricke's work (1904). Much time and energy have been spent in the evolution of silvicultural techniques to ensure pine regeneration but, because of an imperfect understanding of the factors involved, such techniques are almost entirely empirical and, as such, of limited application. By carrying out a few simple physiological experiments in the laboratory, however, it has been possible to arrive at a much better understanding of what is happening in this situation. Kramer and his collaborators first established that shading reduces the rate of photosynthesis, and, consequently, root growth, in pine seedlings more than in hardwoods; it seems that at low light intensities pine seedlings cannot synthesize sufficient carbohydrates to grow root systems large enough to absorb sufficient moisture for survival during summer droughts. The hardwoods, on the other hand, photosynthesize at a higher rate and develop more extensive root systems which enable them to survive where pine fails. Further work, of the kind described

by Bormann, aims at elucidating the reason for the apparently greater efficiency of the hardwoods.

Under the heading 'General Biochemistry', Siminovitch (Canada) summarized his work on the chemical changes in living bark parenchyma of *Acacia* which accompany frost hardening. The increase in water-soluble protein nitrogen (measured electrophoretically) during the period of increasing cold resistance is so marked as to leave little doubt that hardening and protoplasmic changes are intimately related; this work provides an impressive example of how biochemistry can contribute to an understanding of tree behaviour. Mirov (U.S.A.) presented an inventory of the turpentine components present in species of the genus *Pinus* and illustrated the occurrence of chemical mutants—an observation of obvious significance in any tree improvement programme. Finally, Gibbs provided an explanation of the Mäule test for distinguishing the lignins of angiosperms and gymnosperms. A positive Mäule reaction indicates the presence of a syringyl group and, since virtually all angiosperms yield a positive reaction and the large majority of gymnosperms give a negative response, it may be of value in resolving the taxonomic relationships of the vascular cryptogams.

Our lack of knowledge in the field of mineral nutrition was indicated by the fact that two papers only were presented under this heading. Leyton (Oxford) described his work on field correlations between height growth and foliar nitrogen; and Fraser (Canada) discussed the translocation of radioactive calcium and rubidium in the stems of yellow birch and white pine.

In many ways, the session devoted to phloem transport proved the most stimulating. Huber introduced the problem with a beautifully illustrated outline of phloem anatomy and then presented data on the composition and daily variations in concentration of phloem sap. Evidence that the movement of carbohydrates into the sieve tubes is an active process he adduced from the observation that it occurs against a concentration gradient, but concluded that further movement is essentially passive, since a wide range of substances (fluorescein, sugars, viruses, and isotopes) move in the same direction and at similar velocities. Huber's championship of Münch's (1930) mass-flow hypothesis for the translocation of organic substances was supported by Zimmerman (U.S.A.), a student of Frey-Wysseling, in a most impressive paper on the sugars present in the sieve tube exudate of some sixteen tree species. Sucrose has been established as the major translocation sugar, though the higher oligosaccharides, raffinose and stachyose, predominate in some species. Zimmerman postulated three basic requirements for the operation of mass flow through the sieve tube system—the semi-permeability of the sieve tubes to the outside, the permeability of the sieve plates to the translocated solution and the existence of a positive concentration gradient in the direction of flow—and described experimental results with white ash in agreement with these requirements. Observation that turgor of the sieve tube system is maintained after autumnal leaf-fall indicates the impermeability of the side-wall cytoplasm for sugars, and, throughout the summer, gradients are positive in a downward direction, though they are different for different substances.

The Cambridge zoologist Mittler confirmed Huber's evidence of sieve plate

permeability and, while it cannot be claimed that mass-flow has been proved, a mass of evidence is accumulating which is entirely consistent with this hypothesis. Interest in Mittler's data on the chemical composition of sieve tube sap was to some extent eclipsed by admiration of his sampling method. Using stems of willow colonized by aphids, which feed with the tips of their stylets inserted in the phloem sieve tubes, he severed the stylets and collected the sap which exuded from the cut ends. The beauty of this method lies in the fact that the aphids feed from a single sieve tube and the sap collected is uncontaminated by material from other plant tissues.

The session devoted to root growth comprised four papers. The present writer examined the controversial question of winter root growth in trees and described experiments relating physiological activity of *Acer* buds to the initiation of cambial activity and root development. Slankis (Canada) reviewed the problem of mycorrhiza, demonstrating that, with both excised and intact pine roots, the characteristic morphology of mycorrhizal roots can be reproduced in the absence of a fungus by both synthetic auxins and fungal exudates; evidence that the morphology of mycorrhizal short roots is determined by auxin exuded by the fungal symbiont is, thus, convincing.

A paper by Shapiro (U.S.A.) on the growth of root primordia in the stem of Lombardy poplar presented some baffling problems. If cuttings from a dormant stem are placed in humid air in darkness, primordia emerge within 5–7 days; exposure to as little as 150 foot candles of light for 10 minutes daily during the pre-emergence period, however, completely inhibits their development, while light treatment of 1 minute per day reduces the number of roots emerging by 50 per cent. Preliminary studies of the action spectrum of the phenomenon indicate that it is analagous to many photoperiodic responses, in that red light is responsible for the inhibition and it can be partially reversed by appropriate doses of far-red radiation. The findings, however, that both far-red and blue light will inhibit the development of primordia suggest that some of the light sources used may have been contaminated with red light, and further work will be necessary before the analogy with other red/far-red reactions can be established. To end the session, Leyton described Rousseau's work on root growth in relation to aeration, but, in spite of an interesting discussion, no progress was made in answering the old question of how roots of species such as willow can survive relatively long periods under anaerobic conditions.

The heading 'Other Growth Phenomena' covered a miscellany of four papers. Thimann (U.S.A.) described a device for measuring the rate of cytoplasmic streaming in cambium initials of *P. strobus*, and reported that the rate is increased by auxin, retarded by enzyme inhibitors, and is sensitive to oxygen tension and to temperature. The observation that irreversible damage occurs at temperatures as low as 42° C. is surprising, since there is abundant evidence that summer temperatures higher than this obtain under field conditions; specific differences in response may possibly have some ecological significance in explaining species distribution. One wonders, too, whether cytoplasmic streaming is involved in the high temperature protection afforded by substances such as adenine. Thimann was

followed by the American tissue-culture expert, White, who described an unusual tumour which occurs on white spruce in certain limited regions of north-east America. The tumours arise as sectional chimeras originating in single cells of the buds, but the limitation of such cells to particular trees in particular geographical and ecological locations and at a particular stage in development suggests that some extraneous mutagenic agent may be involved. Chemical and physical agents, bacteria, viruses, and even genetic instability due to hybrid origin were all considered as possible factors.

A paper from Brown (U.S.A.) on the auxin physiology of *P. palustris* described an exhaustive series of auxin determinations on plants at various developmental stages, but, unfortunately, could report little progress in attempts to understand the nature of the peculiar 'grass' stage in this species; and a second paper by Shapiro completed the session by describing a number of unexplainable peculiarities relating to polarity and bud regeneration in stem segments of Lombardy poplar. Any confidence one might have possessed in our ability to understand tree behaviour was rapidly dispelled by the papers presented during this session.

The final day of the symposium was devoted to problems of developmental physiology. Opening the first session, on Photoperiodism and Thermoperiodism, Pauley (U.S.A.) stressed the importance of considering photoperiodic response in any programme of tree improvement involving the use of exotic species or races. Illustrating his talk with examples drawn from provenance trials of poplar, he described the effects on length of growing season of moving long-day races into short-day habitats and vice versa. Wareing (Manchester) reviewed the various types of photoperiodic response shown by tree seedlings and described work on the germination of birch seed. At temperatures below 20° C., 50 per cent. germination under conditions of 4 hours light per daily cycle can be increased to 85 per cent. by exposure to light for 20 hours per cycle. Using a birch embryo bio-assay, Wareing has extracted a germination inhibitor from the pericarp of the seed and from mature leaves, an inhibitor which, he postulates, can be destroyed by light, and, possibly, by oxygen; but he also considers that a germination promotor may be involved in the light reaction. He ended an excellent paper by emphasizing the role of leaves in photoperiodic responses. Further growth responses were described by Downs (U.S.A.) and the session closed with a report by Kramer on experiments with *P. taeda* carried out in the 'phytotron' of the California Institute of Technology. Experiments with seedlings grown under various combinations of day and night temperature showed that growth is greatest when there is a big difference between day and night temperatures, and becomes less as this temperature spread is reduced. His results suggest that high night temperatures may be a limiting factor in the southward extension of certain northern tree species and, also, that high night temperatures of midsummer may result in a growth cessation. Should this latter suggestion be confirmed, it may explain a number of important phenological problems.

During the final session, several short papers were presented. Apart from an analysis reported by Bourdeau (U.S.A.) of resin yields in pine, they were all concerned with reproduction. Mirov outlined work being carried out by Stanley

in California concerning the biochemical differences between male, female and vegetative tissues, and presented preliminary data on enzyme analyses of germinating pollen. Sax (U.S.A.) reviewed the many long-standing physiological problems raised by the results of grafting experiments in horticulture; and Stone discussed germination patterns in *P. jeffreyi* and *P. lambertiana* in connexion with seed dormancy mechanisms. A study of flowering in spruce, recently initiated in Canada, was described by Fraser who hopes to correlate flower production with weather conditions, radial and apical growth or variation in moisture conditions on a number of field sites. Data collected will be used to design flower-inducing experiments with young trees exposed to various light, temperature, and moisture régimes. The final paper of the closing session was given by Wareing and was of the same high standard as his first one. From a study of the distribution of cones on individual trees, and from experiments resulting in the induction of male cones by disbudding, Wareing suggests that the annual cycle of cone initiation and development is determined primarily by endogenous rather than external factors, and that the pattern of reproductive development in the tree as a whole is related to 'ageing' within each branch and within the tree. This latter suggestion is an interesting hypothesis and is supported by current work in California on the effects of artificial seasons on flowering in pine.

In retrospect, two features of the symposium seem worthy of comment. In the first place, it is remarkable how many of the problems treated in these papers date back to the early days of plant physiology; and it is encouraging that they are now being tackled with modern methods and techniques. The second feature gives less grounds for satisfaction. It was a disappointment that, in a gathering of such fundamental importance to forestry, professional foresters were so poorly represented. Of the 30 participants, only 8 are forestry graduates and only 2 of these come from Europe. One wonders whether this is due to short-sightedness on the part of the directors of forestry research; or whether it reflects inadequacies in the basic scientific training given by the University Schools of Forestry.

In spite of the paucity of our understanding of tree physiology revealed by the papers presented, the symposium ended on an optimistic note. In expressing the gratitude of the participants to the Cabot Foundation for sponsoring the meeting, Gibbs made the suggestion that a second symposium should be held during the International Botanical Congress scheduled for 1959 in Canada. It was generally agreed that further meetings of this kind would be extremely valuable, and it is to be hoped that Gibbs's proposal will materialize. It is to be hoped, too, that active interest and support for what has hitherto been a neglected field of research will be forthcoming from the various Forest Services of the world.

LITERATURE REFERENCES

Dixon, N. H. (1914): *Transpiration and the Ascent of Sap*. Macmillan & Co.

Fricke, K. (1904): '"Licht- und Schattenholzarten" ein Wissenschaftlich nicht begründetes Dogma.' *Centbl. Gesam. Forstw.* xxx. 315–25.

Munch, E. (1930): *Die Stoffbewegung in der Pflanze*. Gustav Fischer, Jena.

Richardson, S. D. (1957): 'The Effect of Leaf Age on the Rate of Photosynthesis in Detached Leaves of Tree Seedlings.' *Acta Bot. Néerl.* vi. 445–57.

OAK

By N. WYLIE

(*Sometime Deputy Surveyor, Forest of Dean. Now in Canada*)

SUMMARY

Four basic stages in the life of the oak wood (*Quercus robur* and *Q. petraea*) are defined and the factors which should influence the manager's mind when he weighs density of stocking and length of bole against rotation to meet his particular requirements are considered briefly in non-technical language.

THIS is not a scientific article. It is concerned with forestry as an art, and in particular with the art of growing oak. The business of forestry, in this case the business of producing useful oak timber, will not be forgotten. The art lies as well in unravelling the knots in human foresters' minds as in controlling the struggle and rivalry of individual trees in a stand of oak.

Differences extreme and irresoluble arise between the most expert and enthusiastic foresters on the subject of the density at which oak should be grown. On the one hand, there are those who think the denser the better, and who would do little or no thinning for the first 80 or 90 years (they admit the necessity of cleaning at an early stage). These fix their thoughts on great length of bole, timber clear of knots, and the highest possible value for the final product, achieving a high value per acre as well as a high value per tree. On the other hand, there are those who are in favour of getting a good girth on the trees quickly rather than a great length of bole, and who would thin early and heavily with this object in view. They reflect on the short length of timber required for veneers, and the very few purposes for which great length is essential; and they remember the financial advantages of getting quickly something big enough to sell.

It is proposed to bring these keenly argumentative gentlemen into complete accord by dividing the life of the oak into four stages, and considering each stage separately. Let the stages be called A, B, C, and D. They can be given names later. It will be found that the two factions among foresters agree very well on what should be done at each stage. They will differ only over the appropriate duration of each stage. As they will be mentioned frequently, they must, for the sake of brevity, be given names. We will call them after two highly respectable birds, calling the first faction 'Stilts' and the second 'Thicknees'.

It is natural to begin with the final product, an oak wood full of timber. Let us consider, then, the D stage.

D, the last stage, is defined as beginning when the desired length of clear bole has been achieved. During this stage all that is expected of the trees is that they should grow in girth as rapidly as possible.

C is the stage during which the trees, besides remaining healthy and with powers of recuperation unimpaired, are required above all things to add to

their length of clear bole. It is at this stage that whippiness may develop in the crop, particularly if the site suggests, or the market demands, or the ambition of the forester insists on a long length of bole; and at this stage also a pedunculate oak may become so constricted in its crown that it is incapable of developing, when it is given room later on, otherwise than by putting out epicomic branches down its stem. The difficulties of this stage can, however, be reduced, if before it a

B stage is recognized, during which the trees are encouraged and given room to put on a good butt. A tree that enters C stage with a good butt is less likely to become whippy. Of course trees in the B stage will not be putting on butt only; they will first have to put on crown; and it is certain that while they are putting on crown and butt, they will be developing good roots. In fact during the B stage trees will be encouraged, by thinning, to grow from saplings into small, sturdy trees.

A stage is the early stage at which the young oaks are still competing with weeds—bramble, bracken, broom, or whatever there may be. At this stage also very often the trees are most vulnerable to frost. The stage begins at germination, or planting, and ends when the young trees are tall enough to be in no further danger of damage by weeds, and when the forester can walk about underneath them.

The four stages then are:

A. Advance stage or establishment stage.
B. Butt-growth stage.
C. Clear-bole stage.
D. Diameter-growth stage.

The pictures of the stages are not difficult to fill in. In the advance stage in a naturally regenerated wood there are dense clumps of seedlings, some of them of sapling size. A few of these have birch and other species among the oak. In the open spaces smaller seedlings, struggling in the grass and weeds, can be seen on closer examination. Some of these are putting out new shoots after being damaged by frost; others are untouched by frost. In places no seedlings can be found at all, only grass and an occasional 3-foot high oak with the shape of a gooseberry bush. A few old trees of the parent crop still remain. Where the clumps of oak seedlings are densest, they seem also to be tallest. If the young crop has been planted or sown by hand, it is more even; but there is the same competition from weeds, which have to be kept in check; and there begins to appear the same tendency for the densest part of the tree crop to be the tallest.

Nature knows no B stage. If it is recognized it will be of man's contriving. It is begun unconsciously when a forester wants to thin a wood as soon as he can walk about underneath it—or earlier when he decides that by thinning the densest clumps of natural oak he can obtain some good bean sticks. The Stilts, who have had to do with the growing of oak for a very long time, begin a butt-growth stage when they make their cleanings, cutting out birch and sallow and unwanted beech

and hornbeam and taking the opportunity at the same time to remove predominant young oak that have become forked or have been picturesquely strangled by honeysuckle. Picture the crop entering the B stage as close-grown saplings of oak, and perhaps of oak with other trees; emerging from it as well-shaped, stocky young oaks, adequately spaced, having thick butts; other species have been removed or reduced to their proper position, so that they cannot either by numbers or by dominance prevent the development of a final crop of oak.

During the C stage the topmost shoots of all the leading trees extend a foot, or 2 feet, upwards every year at first, less and less as the trees grow older. The side branches grow out until they meet their neighbours, then they can grow no farther; the lower side branches are suppressed and die and drop off; thus the bole below the branches lengthens upwards by a foot or two each year at the middle of the 'clear-bole' stage, less towards the end as the vigour of height growth declines, less also at the beginning if there have been heavy thinnings in the B stage, less at any time after a thinning. While the boles are lengthening, they are growing also in size each year by the thickness of an annual ring all round; but as the crowns of the trees are hemmed in by neighbouring trees, the thickness of the annual rings is not great. So that in the second half at any rate of the 'clear-bole' stage the trees seem to be tall and slim: elegant if they have been lightly thinned: dense and a little ragged-looking if they have not. The C stage occurs in nature: in fact it is only brought to an end in a natural wood by accident, when wind, lightning, and disease make openings in the canopy which permit the crowns of surviving trees to spread.

The oak wood in the D stage, or last stage, is the oak wood which we wish to see: trees with room enough to grow big crowns, fine to look at, large enough to sell at any time, but in view of their health and vigour and their rapid increase in girth and value there is no hurry to cut them. This is the diameter growth stage, the value increment stage, the perfecting stage—at the latter end of it, if cutting is delayed, the capital reserve stage.

THINNING TREATMENT

Now should an oak wood be thinned lightly or heavily?

In the D stage the crowns must have full light, in order that there may be big growth in diameter at the trunk. Also the side branches of the trees at this stage are large and contain heartwood; if they die from suppression, rot may enter through them into the trunk. For these reasons thinning at this stage must be sufficient to enable light to fall on the whole crown, on practically every green branch. There can hardly be disagreement about this.

In the C stage, when the desired length of clear bole is being obtained, there will be little thinning, as the suppression of the lower side branches is the object.

In the B stage, when butt growth is the aim, the best trees must be given plenty of room. There is no other way to get sturdy butts on to the trees. It does not much matter whether the operation of singling the best trees is called a cleaning or a thinning.

In the A stage, when the trees are battling with weeds, the one object will be to

get over this expensive and dangerous stage as quickly as possible. All will agree that a dense crop will get over it more quickly than a sparse one.

At every stage the Thicknees and the Stilts have agreed, or so we venture to hope.

A. Keep dense.
B. Open up.
C. Keep dense.
D. Open up.

Where they differ, of course, is over the length of clear bole desired, and thus over the duration of the C stage.

Let us take two extreme cases. The length of bole desired and achieved, and the time taken might be as follows:

	Length of clear bole (feet)	*Rotation years*					*Yield, c feet per acre*	
		A	*B*	*C*	*D*	*Total*	*Final*	*Thinnings*
Stilts' wood .	50	20	5	75	80	180	5,000	2,500
Thicknees' wood . .	18	20	15	10	55	100	3,000	1,500

There are sites and circumstances in which either policy might be justified.

The figures which have been given in the above table are mainly guesses. They have, however, a background in a study of the Hessen Yield Tables (Anon., 1913) and in recollections of the Forest of Dean and Wye valley oaks. The scheme of thinning in Thicknees' wood has produced a substantial crop of timber in a relatively short time, 100 years. In Stilts' wood a bigger crop has been achieved in a much longer time, 180 years: there has been a long C stage, following brief, perhaps inadequate, attention in a B stage when the crop was between 20 and 30 years old. In Thicknees' wood the B stage was longer and more thorough.

Further technical reasons for the procedure advocated are given below.

DIFFERENT SITES

Let us first consider different sites, and the rotations and objectives which may

	Length of clear bole	*A*	*B*	*C*	*D*	*Total*	*Age of max. M.A.I.*	
							Volume	*Value*
Good site .	40 ft.	20	10	60	60	150	110	140
Poor site .	20 ft.	30	10	30	100	160	140	155

M.A.I. = mean annual increment, or total yield divided by the number of years of growth.

be suitable to each. Compare two crops, one on good land which might in different circumstances have been used for agriculture, and another on poorer land. Here the rotation may be about the same, but in the second case the

objective must be limited, as any attempt to obtain a great length of clear bole on poor land may result in the trees never reaching a useful diameter.

On the poor site the trees are brought to a girth comparable to those on the good site by using a very slightly longer rotation and more particularly by attempting only 20 feet of clear bole instead of 40 feet, thus shortening the C stage and allowing time for a long D stage.

DIFFERENT POLICIES

Now let us consider two different policies, as might be exemplified in the town forests of towns *P* and *Q*. Suppose the two forests have an equal capacity for growth. The principal object of management of town *P* is to secure the maximum financial yield: a secondary object is recreation: it is believed that oak on a rotation of 150 years will best achieve these ends. The policy of town *Q* in the management of its forest is a little different: it is partly to obtain an annual revenue, and partly to hold a reserve of timber in case of calamity or exceptional needs (e.g. building). The forest working plan has been framed accordingly and rotation is fixed at 180 years, that is 30 years above the estimated financial rotation. The town buildings and property are covered as to part of their value by an ordinary insurance policy and as to the other part by the excess of timber standing in the forest above what would be there if the rotation were 150 years. To obtain money for rebuilding a town hall that has been burned, or for some other special need, it may be decided to make exceptionally big sales of timber from the forest, up to a maximum of 30 years' growth. (Of course these extra large sales cannot be made many times in a century: and they must be followed by a temporary adjustment of plans both for forest management and for insurance, until the former situation has been restored.)

The decision by town *Q* to hold a reserve of timber and with this object to lengthen the rotation, barring accidents, to 180 years will allow the trees to grow a little taller and a good deal larger than trees grown to 150 years: and it will not be difficult for a succession of skilful foresters to obtain a rather greater length of bole clear of branches. The duration of the stages will be a little different in each case.

Town forest	*Length of clear bole (feet)*	*Rotation years*					*Yield, c feet per acre*		*Age of max. M.A.I. value*
		A	*B*	*C*	*D*	*Total*	*Final*	*Thinning*	
P	30	20	15	55	60	150	4,500	3,000	150
Q	40	20	15	75	70	180	5,000	3,500	150

We do not hear of many town forests in the British Isles at the present time but there are government forests and private forests with their different aims. In each there is a complete range of sites from good to poor; and also there are local differences in markets and in history, so that in different places different rotations will be adopted. On average it may be expected that private owners, as they are interested in obtaining the greatest financial yield, will choose rotations which are

not too long: while the government will perhaps prescribe rather longer rotations, in planning the management of some of its woods, in order to build a reserve. The longer rotation will permit a greater standing volume and a longer average length of clear bole: this will suggest a long C stage (clear-bole stage) and some preparation for it.

BRANCHING AND KNOTS

It may be asked whether these stages need be sharply defined.

A. Keep dense.
B. Open up.
C. Keep dense.
D. Open up.

Indeed, whether they should be recognized at all. Why should not the crop be opened out evenly throughout the rotation? So far the only reason given for a C stage (in which the crop is kept dense) is the need for a certain length of clear bole to obtain timber of quality and predictable strength: and for a B stage the need to guard against whippiness developing later on in the C stage. There are two other considerations which lead to the same conclusion. Let us take the essential one next. It is concerned with branches as we see them on the growing tree and with knots as we find them in the sawn timber.

A large branch on an oak tree, say 5 inches in diameter or larger, is contributing to the growth of the tree so long as it remains alive. The amount it contributes could no doubt be found by experiment. For the present it may be conjectured that ten 5-inch branches, open to the light, will contribute a cubic foot of timber to the main trunk every year, 10 cubic feet in 10 years: that is £2 worth of timber every 10 years from ten 5-inch branches. The branches will look much the same in Stilts' wood and in Thicknees' wood; only in Thicknees' wood they will be 20 to 30 feet above the ground and in Stilts' wood 50 to 60; and in Thicknees' wood as little as 60 years may have elapsed since the acorns sprouted, whereas in Stilts' wood more than 100 will have gone by. In each wood the ten branches may be adding to the value of the bole at the rate of £2 in 10 years or £10 in 50 years: in one case by adding wide annual rings over a short trunk and in the other narrower annual rings over a long trunk. If the tree is cut down while the branches are alive, they will appear as live knots and the part of the timber containing them will be disqualified for some purposes, but will not be useless.

Now these branches have only remained alive and productive because they have received enough light, either direct or reflected off neighbouring trees. If, however, they are too close to neighbouring trees and grow out into them, and light is cut off from them by branches growing above them, then they die or they are weakened and partly die. They can contribute no more to the volume of the trunk. Loss £10 in 50 years—for every ten 5-inch branches deprived of light by crowding. Further loss—large dead knots in a part of the log—5 or 6 feet rejected at the mill—£1. Still further loss—rot enters through the dying branches and spreads a little way down into the trunk—say 10 cubic feet in 50 years—£2. That is an estimated loss of £13 in 50 years. If, on the other hand, the ten branches

are kept alive by removing in good time some of the neighbouring trees of lesser promise, the £13 is saved. There is, of course, the loss of increment on the trees removed but this is not likely to be very much.

Oak woods in which many of the trees have branches of 5 inches in diameter or more are, of course, already in the stage which has been named the D stage or diameter-growth stage. If a wood in this stage is inherited, and it is seen to be too crowded, the wood need not be thinned to its proper density all at once. It can be done in two or three thinnings. An oak tree that has been long restricted on all sides will make a more certain response if it is opened up on one side at a time (this was field advice once given the writer by W. H. Guillebaud). The tree will not then be given more light than its present complement of buds, twigs, and branches are able to use, and its still thin bark will not be exposed too suddenly to the severities of heat and cold.

The D stage is distinguished from the C stage because in every forester's mind there is a critical size of branch (*c* inches in diameter) *above* which the branch is too valuable as a living part of the tree to lose, and would make too hideous a knot in the timber if it were allowed to die; and *below* which a branch may become suppressed and die and fall off without harm to the growing tree and with the advantage that the timber will be freer of knots. The C stage must come to an end and the D stage begin when the larger branches have reached this diameter, even if the intended length of bole has not been reached.

What value will be given to *c* in an oak wood? Probably no forester would put it higher than 4 inches or lower than 1 inch. Perhaps the majority would put it between 1½ and 2½ inches over bark. It would be decided after local investigation. In some forests the size at which heartwood begins to form in the branch may be taken as the critical size. In others this may be deemed of no importance, as there may be local observations of rot entering the trunk through sapwood as well as through heartwood. It is a point worth looking at, however.

Through the C stage branches must not exceed *c* inches. When they do exceed *c*, the D stage has been reached. It may have been reached intentionally or unintentionally, but in either case it must be recognized, and thinning from then on must be continuous.

If the branches are going to approach *c* inches in size at the end of the C stage, why should they not be brought to this size (on the lower part of the trunk) at the very beginning of C stage, if that will result in bigger growth in diameter and volume on the best trees? Then there need be no thinning in the C stage at all. Already at the end of the B stage the wood would have been thinned to the point where the branch diameter approached *c* inches, and the forester making the thinnings would have come to learn at what average spacing of trees this point is reached. However, there is another consideration, namely, that a proportion of the trees, including some of the largest ones, may become forked, cankered, or cracked, which obliges the forester to leave rather more trees standing to the acre at the beginning of the C stage than at the end of it. So he will thin in the B stage with a view to achieving a maximum branch size somewhere between ½*c* and *c* inches, according to his judgement.

In the foregoing tables, which are given for illustration, the periods of the four stages are not intended to be prescriptions, but are simply first estimates. Prescriptions, or rules to guide the forester, will be:

(1) Length of clear bole to be achieved if possible (recognizing that this may have to be reduced on patches of poor ground or where accidents to the crop have occurred).
(2) Maximum diameter of branch allowed during the C stage: perhaps also some advice as to the size of branch to be achieved at the end of B stage. Advice on the spacing of trees which will result in the required branch size can be given, when this becomes known.

VOLUME

A further reason for opening up the crop in the B stage is the simple one that there will be more volume put on the best trees. Suppose, for example, that in one part of a wood an acre is opened out well, so that the best 50 trees enter the C stage with an average diameter of 10 inches measured 8 feet from the ground and have good crowns, and on another acre through the lack of thinning the best 50 average only 5 inches and have small crowns. Suppose further that for the next 20 years the 100 trees grow in diameter at the same rate (this is an unwarranted assumption, but one which it may be safe to follow a little way for the sake of demonstration), and that rate of growth is ten rings to the inch. Then after 20 years the first 50 trees have a diameter at 8 feet of 14 inches, and the under-thinned 50 a diameter of 9 inches. The first 50 would already yield 16-foot logs, averaging 13½ cubic feet, whereas the other 50 would only give small 16-foot logs averaging 5½ cubic feet. If the tops of the trees, above 16 feet, were taken into account, the difference would be greater. The trend is obvious. This is a purely mathematical calculation: it is not based on any measurements of trees. A study of the measurements of oak sample plots, e.g. those at Bradley Hill in the Forest of Dean, show the larger girthed trees occurring in the more heavily thinned plot. But it is the early opening which it is believed will give the spectacular result. The recorded treatment and measurement of the Bradley Hill plots started late in the crop's development. Probably all the plots, not only the one chosen for heavy thinning, had a thorough opening up in early years, when some conifers were removed.

MIXTURES

It is easiest to understand the scheme of this article if the imagination follows the growth and development of a crop of pure oak. We may, however, want to grow the oak in mixture. An instance of this would be when a reserve was being built up and the claims of Douglas fir, Western red cedar, and even Western white pine (if a resistant strain can be found), were being considered along with sessile and possibly pedunculate oak, as trees of high value, more vigorous and less liable to defect in the second century of their growth than in the first.

Or we may wish to grow the oak in mixture with other trees for the first 80 years of its life. An example would be on the older, heavier, and limier soils of the

Old Red Sandstone where a few valuable ash might be grown with the oak. On the newer and lighter woodland Old Red Sandstone soils, some larch might with advantage be mixed with the oak.

The same principles will apply in all these cases, only there will be more subtlety in timing the thinnings, more pleasure in marking them, and more profit in carrying them out.

LITERATURE REFERENCE

Anon. (1913): *Ertragstafeln zum Gebrauche bei der Forsteinrichtung*. University Printer, Giessen.

SCIENTIFIC AND INDUSTRIAL RESEARCH

Reconsideration of Main Tasks for the Department

The first report of the Council for Scientific and Industrial Research was published in May 1958 for the period ending 31 December 1957 (Cmd. 428. H.M.S.O. Price 4*s*. net) and in it the Council reviews in its new capacity as an executive council instituted under the Act of 1956 the main problems before it in the light of the altered conditions of the present age.

The report notes that the Department of Scientific and Industrial Research was formed in 1915 to promote civil research in science and technology at a time when neglect of research had led to grievous consequences in war and that since then pure and applied science have made enormous strides both in industry and at the universities.

The report explains that behind this development lie three important groups of changes. Firstly whole industries based on science have grown to maturity while entirely new industries have emerged. Secondly most of the larger industrial units have set up their own research departments while all units, however small, may benefit from membership of specialized research associations. Thirdly the days of the pioneer scientists are almost over and an increasing amount of research must be organized on a very large scale. These changes have affected the fundamental tasks of the Department and consideration of the part it should play in the conduct of pure research and in research of direct application to industry will occupy the Council for some time to come.

As regards specific action taken by the Council to date, it has considered first those stations of the Department which offered clear-cut problems to solve. One of these was the Forest Products Research Laboratory and here the Council have arranged for the Timber Development Association, who receive a grant from the Department and who have recently set up a research establishment at Tylers Green, to take responsibility from 1 January 1958 for some applied research which the Council feel should be more suitably undertaken by them. Items transferred include research on the strength properties of timber, kiln drying, utilization of wood waste, and the advisory services.

The research programme for the Laboratory since announced provides for the initiation of research on the pulping properties of home-grown timbers and for increased research on their general properties, while expenditure of public money on items transferred is to diminish progressively and end in five years. This suggests less precipitate action than first indicated and will, we trust, ensure continuity after transfer of the high standards of impartiality and accuracy always maintained by the Laboratory.

THE MIDLAND WOOD SOCIETY CONFERENCE, 1958

Growing quality timber

THE Midland Wood Society's third open conference was held at the Shropshire Adult College, Attingham Park, from 18th to 20th April 1958. Invitations were issued and there was a large attendance. After being welcomed by the Warden, the company was addressed by the Society's Chairman, Mr. G. A. G. Miller.

Mr. Miller—himself an architect—expressed the satisfaction of members that the Society's initiative in bringing together growers and users of timber had resulted in similar meetings being arranged by other bodies, i.e. at Dartington Hall in 1957 and at Northerwood House in 1958. The link which the Society had forged was further strengthened by Lord Bradford becoming their President.

The following papers were read:

'The Influence of Site Conditions': PROFESSOR ANDERSON.

'The Effects of Some Forestry Practices': MR. F. ALDRIDGE, MR. R. HUDSON (Midland Wood Society).

'Stand Treatment': PROFESSOR ANDERSON.

'The Improvement of Timber Quality by Selection and Breeding': MR. J. D. MATTHEWS.

'Utilization of British Softwoods': MR. GORDON JACOB.

Exhibits were shown and there were discussions following the reading of papers and a general discussion on the final morning. Among those who took a principal part in the discussions in addition to the readers of papers were Major Pilling, Messrs. Rendle, Penistan, Munn, Charles Venables, Grayson, Eades, and Dr. Phillips. A visit was also paid to Lord Bradford's highly interesting mixed woodland at Ness Cliff where the party was shown round by Mr. Hutt. There is here a remarkable natural re-seeding with larch.

The meeting was most useful and enjoyable. Growers, buyers, processers, and users of timber were all represented and are indebted to the Midland Wood Society and the College for making it possible.

While much that was discussed concerned matters of basic principle, controversial issues were raised as well, notably in the paper by Messrs. Aldridge and Hudson. It is not possible to analyse these in a short note, but reference may be invited to their 'Growing Quality Softwoods' in the *Quarterly Journal of Forestry* for April 1958, to the paper by Rendle and Phillips printed in this number of *Forestry*, and to the summary of the Northerwood conference also printed in this number.

NORTHERWOOD CONFERENCE, 1–4 MAY 1958

The management of coniferous crops

SUMMARY BY A. J. GRAYSON

IN welcoming members to the conference, Sir Henry Beresford-Peirse explained that the idea of holding such gatherings had arisen more than two years earlier following the successful conferences held by the Midland Wood Society, when it was felt by three of the present participants, the Earl of Bradford, Mr. Hiley, and himself, that there was a need for an informal conference on the subject of the aims of foresters in Great Britain. Accordingly, a number of growers, consultants, timber merchants, and technologists had been invited to Dartington Hall in 1957,* and again this year invitations had been sent to a number of individuals. The subject chosen for the present conference was intended to limit the discussion somewhat and it had been decided to concentrate upon the management of coniferous crops with particular attention to the economic production of sawtimber.

First session. Lord Bradford took the chair, and the subject considered was that of the influence of species, rate of growth, knots, size of log, and other characteristics on the cost of milling and the value of the sawn lumber. Mr. Finlay Wilson took as his starting-point the needs of consumers of sawn timber. He had conducted a survey (covering 1 million standards) of the size distribution of imported sawn softwood, and this showed that the average size of imported material was 15 feet long, 7 inches wide, and 2½ inches thick. There was no doubt about the size of the market open to home-grown produce. In relation to rate of growth, his own experience showed that our fastest-grown softwood was saleable as lumber even where growth rings of ⅛ inches were included. He concluded that we should continue to grow our conifers as rapidly as at present, that logs 15 feet in length and of 10 inches mid-diameter were suitable for sawing and that only small reductions in milling cost combined with small appreciations in value could be expected where logs of larger diameter (say 18 inches) were handled.

Mr. Rendle set out to describe the factors affecting the inherent quality of sawn softwood timber. Density varied considerably according to species, ranging from 23 lb. per cu. ft. in the seasoned condition for *Thuja plicata*, to *Pinus strobus* 24, Sitka spruce 25, Norway spruce 28, *Pinus radiata*, silver fir, western hemlock 30, Corsican and Scots pines 32, Douglas fir 33, Japanese larch 34, European larch 37, and pitch pine 43. In some species the wood substance was distributed very unevenly between springwood and summerwood, and it was preferable to have a more even distribution as found in *Thuja*, *P. strobus*, and *P. radiata*. In a plantation-grown tree showing the typical growth pattern, wood formed in middle life was of better quality than the core of juvenile wood because the summerwood

* A note on the earlier conference, written by W. E. Hiley, appeared in *Forestry*, xxx. 138, and a fuller account by A. J. Grayson will be found in *Quart. J. Forestry* for Oct. 1957.

tended to become not only denser but also wider as the tree increased in age. It was a pity that the low quality of the juvenile or core wood had been associated with ring width. Too much significance had been attached to ring width; the connexion between strength and rate of growth should be regarded as casual rather than causal. In middle life, the ring width might vary within wide limits without very much effect on strength. Thus rate of growth was not a primary factor affecting quality, it was rather an index of quantity. It had also to be remembered that two of the virtues of coniferous timber were ease of working and lightness in handling. For general utility softwood the optimum density might be of the order of 30 lb. per cu. ft. air-dry. While time did not allow Mr. Rendle to discuss natural durability, knots, spiral grain, compression wood, and microscopic features, he said it was recognized that there was a need to review laboratory methods of evaluating timber, so that a closer understanding of the relation between inherent properties and money value could be gained. Finally, Mr. Rendle pointed out, in the past too much importance had been ascribed to small differences which did not affect the commercial value. If the bulk of the timber grown fell within the limits of a rather wide specification for general utility timber, we would not need to worry about slight differences in technical properties.

In the discussion which followed attention was first directed to the questions of ring width and knottiness. Mr. Jacob raised the topic of the size of market open to saw-timber displaying wide rings; but this issue was felt by Mr. Finlay Wilson to be of minor importance since experience with material from his mill was that a ready market existed in carcassing timber and in the packing industry. The combination of Mr. Wilson's evidence and that of Mr. Scott to the effect that similar experience held in the case of Chilean-grown *P. radiata* together with Mr. Rendle's discussion of the problem appeared in effect largely to diminish the importance often given to ring width. Dr. Hummel pointed out that in any case very little of our total production in future would be of the wide-ringed timber handled by Mr. Wilson. With regard to knots, however, Mr. Sangar said that it had to be recognized that this defect should not be lightly dismissed. Too often the tests of home-grown thinnings made by the Forest Products Research Laboratory showed that timber was down-graded on account of knots.

Two separate issues arose in connexion with the economics of sawmilling. Mr. Hiley said that where trees grew rapidly a heavier thinning régime than that in the British Yield Tables allowed main crop trees of 18 inches diameter to be grown without extra cost (adopting on grounds of general acceptability growth rates of six rings per inch). Thus it became necessary to extend the range of inquiry into sawing costs. Not only was sawing (with the appropriate machinery) likely to be cheaper with large logs, but also the value of the lumber would be higher. He expressed the hope that the conference would endorse his proposal that more research should be devoted to these practical questions.

Apart from sawing costs the other economically important question of the volume of sustained supply needed was touched on. Sir Henry Beresford-Peirse propounded the theory of regional planning to meet the requirements of

individual or small numbers of mills. Both Lord Bradford and Sir Richard Proby supported this approach and pointed out the usefulness in this respect of the Woodland Owners' Association recommended by the Watson Committee.

In summing up, Lord Bradford said that our ignorance of costs and mill characteristics was a marked feature of the discussion and pointed to the vital need for more research.

Second session. Sir Richard Proby took the chair and the session was devoted to a survey of costs of growing, extraction, and transport of saw timber as influenced by species and size. Mr. Chard reviewed the subject from the point of view of Forestry Commission experience. He pointed to the need for an effective accounting system to serve as an aid to management, both in the role of a guide to current expenditure and revenue, and historically for the purpose of comparing various methods of working. The cost of growing saw timber could not be divorced from the question of thinnings. He advocated early thinning and the removal of not less than 150 cu. ft. per acre. With low, as opposed to crown thinning, more uniform sizes were produced, while these could more conveniently be handled by men, while horses only became necessary for extraction in the second thinning when there was more room in which to work.

Major Brodie held that in forestry, as in any other undertaking, the cost of producing the final article must be known. He proceeded to describe a simple method of determination which defined cost of production as the sum of expenditures on a plantation where each item was discounted to the first year of the rotation, divided by the sum of the discounted volume yields. Using this method (by contrast Mr. Hiley's method of calculation incorporates the relative values of the separate volume yields) he came to similar conclusions, namely, that the grades of thinning advanced in yield tables for many of the exotic species were believed to be economically unsound, and to reflect too heavy levels of growing stock; while his numerical demonstrations were much speeded by the use of multipliers fixed for any species, quality class, and management régime by the relationship of volume yields to each £ of initial expenditure.

Third session. With Mr. James Macdonald in the chair, the meeting concentrated on the effect of silvicultural systems on the costs of growing timber. Mr. Sangar explained that he was not concerned with the discussion of the various silvicultural systems developed and recognized in countries with very different conditions from our own. He divided the costs of production of the final saw timber into three components, namely, direct, indirect (rent, interest, administration, &c.), and a negative element of credits from interim returns, sporting, and the like. He pointed out that scrub and devastated woodland should be regarded as providing a forest of sorts, which could be led on to a more productive condition by care and attention. Expenditure on work which produced an appropriate enhancement of growth should be unhesitatingly accepted. In regard to the number of plants introduced, or used in afforestation, very little basis except precedent existed for present practice, and our typical spacings often led to unprofitable first thinnings. A most important item was the charge due to interest, and Mr. Sangar emphasized that he wholeheartedly accepted compound interest as the

best available yardstick in assessing the accumulation of cost. If the capital investment in a crop were reduced the possibility arose of introducing a second crop in its shelter, leading to the establishment of a two-storied forest. Final felling should be carried out at the mean of the optimal financial rotations of the two crops.

Mr. Finlayson, who followed, made a strong plea for the adoption of silvicultural systems shown by continental experience over the past three centuries to yield the greatest economic and social benefits. Though lately, he said, it had been the fashion to decry continental forestry, the quality and increment of timber was increasing in the forests managed on a proper silvicultural basis, while the capital employed was decreasing. Tradition was the only solid basis on which to found forestry practice. True, there were no data with which to compare silvicultural systems properly on any scale. Comparable costs would not matter if we had them, for more important criteria existed. The avoidance of wind damage, for instance, was traditionally effected by the adoption of irregular forestry, and it was surprising to hear people still advocating clear felling and replanting in this country where wind is acknowledged to be an important factor. Selection forest produced the ideal condition by developing big trees putting on good quality timber. Summarizing, he said that there were more important factors of which the Faustmann formula could not and did not take cognizance. Subsequently, Mr. Finlayson amplified his views on the distinction between growing tree crops and the practice of forestry. The objects of good forestry should be to produce timber in perpetuity, and to produce the maximum volume of the best quality to the greatest profit. The true condition of forest was as a stable form of vegetation.

The discussion largely centred on the widely divergent views of the majority of members of the conference from those held by Mr. Finlayson. Mr. Sangar, referring to silviculture as 'both the limiting and enabling factor in management', stated perhaps most explicitly and briefly an object of management which clearly met with the approval of most participants, namely, that the ultimate objective was to secure and sustain the maximum volume production in the shortest appropriate time with the minimum use of resources, both human and material. Professor Steven said that clearly the good forester was not controlled solely by economic considerations; but he very properly took them into account in deciding his course of action. He believed that if we made use of the variation in our sites by suiting species with different rates of growth to them, we were bound to achieve a certain measure of group structure (with differing ages represented) and this development would meet some of the objections of those who disapproved of large-scale clear fellings. Mr. Sangar criticized the adoption of continental tradition on the grounds of its deadening effect.

In summing up a somewhat diffuse discussion in the course of which Mr. MacGregor had pointed out the clear distinction between technical and economic efficiency, Mr. Macdonald said that desirable as it might seem to practise the type of forestry Mr. Finlayson advocated, we were forced to adopt 'non-forestry' for the present. It was quite essential to pay attention to the circumstances in which the country found itself, and forestry had in some measure to be adapted to the economic conditions of the time.

Fourth session. This brought the conference to a central theme of the meeting and of British forestry practice today. Under the chairmanship of Professor Steven, Mr. Hiley and Mr. Hills read papers on the effects of thinning and pruning on the costs of growing timber. Mr. Hiley claimed that there was a need for considerable changes in the practice, research, and teaching of thinning methods. Fresh methods, when applied, would produce more and better timber and make it available earlier. On the Forestry Commission's properties alone there was a possibility of a net gain of some millions of pounds a year. There was a great contrast between the costs of production under the thinning régimes of the British Yield Tables and more progressive régimes. In order to answer the question of how one should thin, a programme of research was needed which would cover the following topics: (*a*) cost of sawing (and in this matter we should not be too easily persuaded that small logs could be sawn more cheaply per cubic foot of sawn lumber than large logs); (*b*) value of the product; (*c*) cost of growing. On this point it was important to know how thinning grade affected increment. But our yield tables did not extend far enough; business management required some intelligent guesses, and we should do as the South Africans had done and extend our tables beyond the ages for which predictions could be made with complete scientific assurance.

In discussion, Dr. Hummel commented on recent German evidence concerning the effect of stand density on increment. He said that Assmann working with Norway spruce claimed that a certain optimal basal area gave slightly higher volume increment than others. However, he felt it dangerous to draw definite conclusions from Assmann's work on the grounds that the experiments started comparatively late, that the thinning treatments had not been applied consistently over the 30–40-year period considered, while, in addition, the customary close spacing (4 feet) of German plantations might have had some effect.

Mr. Rendle, speaking on the subject of research required, emphasized the necessity for a link between technical and money values. Thinking in terms of half a century hence, he believed that it would be very rash to depend on high prices holding for narrow-ringed timber: the speciality market was something of a gamble. Mr. Jacob felt it was impossible to divorce pulpwood from sawtimber in discussing our aims and methods. He had suggested the growing of small trees because he believed that foresters wished to produce such material. Many thinnings containing much core wood and heavy thinnings yielding poor quality tops were unprofitable to handle. Mr. Richards provided some information on the production overseas of chipboard from fast-grown pines. Low quality wood could be chipped for the interior of sandwich-type boards which were faced with specially prepared chips of higher quality. Alternatively the board might be made up of chips of a uniform type faced with veneers.

Mr. Hills then gave his views on pruning and related his experience gained during the last 15 years. He paid tribute to the service done for forestry by Captain Wolryche-Whitmore who had developed a most efficient tool in the form of a pruning chisel, and had also evolved the appropriate techniques for using it. After detailing the important advantages arising from pruning, Mr. Hills

stated his recommendations for treatment. He advocated early pruning (i.e. between 8 and 10 years for fairly fast growing trees) and a pruned bole of one-third of tree height in the early stages, rising to one-half or three-fifths in later life.

Summing up the discussion which followed, Professor Steven said there was an obvious need for inquiry into the advantages of pruning, though its wide-scale practice might be prevented by labour shortages. With reference to thinning he observed that the original policy of the Forestry Commission aimed at the production of sawn lumber from the final crop and later thinnings, and other products, e.g. pitwood, from the earlier. There was, however, the choice between the provision of fewer large trees by heavy thinning, or of smaller trees by lighter. We had to base our policy on knowledge of what our essential needs were, and in this respect we were not necessarily in the same position as Craib had been, for we had the choice of producing pitwood and pulp as well as lumber.

Fifth session. Sir Harry Champion took the chair for a general discussion of points raised earlier with special reference to desirable forest and forest products research. Sir Henry Beresford-Peirse began by alluding to the new appraisal of policy currently being undertaken. We were passing, he said, from the era of building up an undefined reserve to a more strictly economic approach. The object was now rather to make the greatest money yield with due regard to the amount of capital employed, as well as the maintenance and improvement of soil conditions. On the technological level, it was clear that the structure of the tree was arranged the wrong way round from the user's point of view; the core which was required to be large for the subsequent laying on of valuable sawtimber posed a problem for pulp processers and users of pitwood. It was admitted that the achievement of the right pattern of growth for sawtimber was a very difficult problem, and we had to realize that for research into thinning methods a whole range of spacing and thinning treatments from the conservative to the ridiculous should have been laid down earlier.

Mr. Macdonald said that he considered our greatest lack was the shortage of information on the properties of the material we produced. The first priority was, then, the determination of the basic qualities of home-grown softwoods. The Forestry Commission were now supplying for testing at the Forest Products Research Laboratory, timber of known history which would make possible the relation of quality to species, site, and silvicultural treatment. Secondly, we might expect very great technological changes that would especially affect the use of timber; a very close and continuing study was therefore required of trends in utilization.

Mr. Hiley reiterated that the need for research was urgent. He was disappointed with the statement on the programme to be adopted. The information from forest products research would take years to produce, and meanwhile we should, by our thinning, be perpetuating wasteful practices.

Mr. Grayson held that a close study of future relative price levels of various categories of wood products was most desirable as part of an inquiry into timber trends. Such a study would have to take into account the risks involved in aiming

for any particular type of product, but, more important, it would be of value in assessing in which lines technical research might be most rewarding. Dr. Wilson suggested that rather than waiting for research on a broad front, it would be better to dissect the problem into regional studies likely to yield early results. Col. Stobart supported this view and referred to the influence of transport costs on marketing.

Mr. Scott considered the problem from the viewpoint of the market needs, our largest being housebuilding, packaging, and pulp. He recommended that we look to the south-eastern states of America where pine forests were managed for the production of sawtimber and pulpwood. In this country we could get good results for many purposes with wide-ringed (and possibly lower density) material.

Mr. Sangar said it was essential that the objective of thinning be known. All too often thinning was undertaken simply for the sake of thinning. Research was especially necessary on the topics of diameter increment and specific gravity of timber. With knowledge so gained, the forester could decide the grade of thinning to be adopted to reach his particular objective.

Sir Harry Champion said that the variety of conditions of growth and management made a statement of aim necessary and we could go a long way towards providing this. But more research was needed on the interrelated topics of the effect of thinning on volume and quality, and wood technological properties generally, as well as the price-levels and trends observable in utilization. Decisions must be taken, and a knowledge of trends would help managers to decide their courses of action.

Sixth session. At the final session, Sir Henry Beresford-Peirse invited Mr. Rankin to give his views on the needs of a developing forest industry in Britain. In the early years, Mr. Rankin said, the biggest contribution would come in the smaller sizes, and he felt that the matter of the choice of conversion plant was most important. In line with the dictum that had been ascribed to Craib (namely, that forestry was 25 per cent. growing, 25 per cent. processing, and 50 per cent. selling) sales might be held to be the key factor, for with the vast throughputs of modern sawmills continuous sales pressure had to be applied. The 'bread and butter' of the millers' trade would be Scots pine, Sitka spruce, and Norway spruce, and we should concentrate on the treatment of these timbers.

Proceeding to a further discussion on the needs of the forester in the field of forest products research, Mr. Macdonald pointed out that a comprehensive list of projects had been discussed with the Forest Products Research Laboratory, and this covered all the leading questions of interest from the grower's point of view. Mr. Hiley hoped that future work would strike a new line independent of past conceptions. Research institutions, he said, should lead in practice and thought.

In a brief summing up of the session and the conference, Sir Henry Beresford-Peirse made the following points: (*a*) we might assume that there was a fair degree of freedom for foresters to plan their forests in the way they thought best—whether with an economic view in mind or not, (*b*) the concept of sustained yield was accepted, while (*c*) the problem lay in the form which the yield took, and in its

cost of production. The conference had not come any closer to a decision on desirable size or quality of tree, except that it had recognized how unrealistic it was to suggest that a close specification should be laid down for the country as a whole; there might well be advantages, however, in settling objects of management for limited regions. Research had been discussed at some length and one clear point had been established, namely, that long-term fundamental research, particularly on thinning and timber properties, was a matter of high priority. However, it should not be thought that nothing could be done until we had the results of research. Some woodland managers had decided their objectives and determined the costs of attaining them. Without implying any less attention to other sides, more emphasis was definitely necessary in future on the economic and commercial aspects of forestry.

Names of participants in the conference:

Major C. P. Ackers, Sir Henry Beresford-Peirse, the Earl of Bradford, Major D. J. Brodie, Professor Sir Harry Champion, Messrs. J. S. R. Chard, W. Finlayson, A. J. Grayson, W. E. Hiley, A. L. Hills, Dr. F. C. Hummel, Messrs. Gordon Jacob, J. Macdonald, J. J. MacGregor, F. G. O. Pearson, Sir Richard Proby, Messrs. K. N. Rankin, B. J. Rendle, E. G. Richards, W. J. Riddoch, O. J. Sangar, C. W. Scott, Professor H. M. Steven, Colonel G. K. Stobart, Mr. Finlay Wilson, Dr. S. E. Wilson, Mr. E. Wynne-Jones.

NATIONAL DIPLOMA IN FORESTRY

We have referred to this Diploma recently in these pages and more recently still the Council of this Society has noted its increasing standing and importance in forestry education.

At the most recent examination, two out of five candidates were successful and, for the first time since the Diploma was instituted in 1952, one of them gained distinction in all four groups of subjects.

The written portion was held simultaneously in Edinburgh, London, and Baronscourt in Northern Ireland and the oral portion in Edinburgh and at Dalmeny. The Examiners were Mr. J. B. Hendry, Woods Manager, Atholl Estates, and Mr. A. E. Aitkins, Consultant Forester, Tilhill, Surrey.

ANNUAL EXCURSION OF THE SOCIÉTÉ ROYALE FORESTIÈRE DE BELGIQUE

In the year of the Universal and International Exhibition at Brussels, the Société Royale Forestière de Belgique invited a number of 'guests of honour' to its annual excursion to the forests in the Bouillon and Florenville district of the Ardennes. Representatives of both state and private forestry in France, Switzerland, Luxemburg, Holland, and the Federal Republic of Germany attended. The Société was a little uncertain whom to invite from Britain, but decided to ask the Society of Foresters of Great Britain, which appeared to embrace all interests, to send a representative. In view of the proposed visit to Belgium in 1960, M. J. Penistan was asked to go, and duly attended.

The excursion covered two days and some 100 members and guests took part. The rendezvous was the very picturesque town of Bouillon, and here on the evening of the first day the Société banqueted. The President's welcome was acknowledged in a magnificent speech by Monsieur de Vaissière, Inspecteur General des Eaux et Forêts of France, who spoke for all representatives.

On the first day we saw conversion from hazel and hornbeam coppice with oak standards to beech high forest in an advanced and successful stage on the Jurassic fringes of the Ardennes, some precocious Japanese larch plantations, and very fine mature Norway spruce in Communal Forests near Florenville.

On the second, which started at 7.45 a.m., we were shown highly successful transformation of coppice with standards by group working in the excellent Belgian manner of multiple cycles (8 and 4 years for broadleaves, 12, 6, and 3 years for conifers) with control enumerations in the Communal Forests of Chiny. Thence, with a brief stop to see Japanese larch in the thinning stage—effectively crown thinned—we saw transformation of spruce plantations by group felling in the method evolved by Mons. Turner, to mixed conifer and broadleaved planting. There is an unwarranted tendency to abandon spruce rather blindly for Japanese larch and Douglas fir, both less versatile timbers, but this is a natural reaction from pure, even if magnificent, spruce. We saw and discussed fine new forest roads, then saw and wondered at prolific and unexpected Norway spruce regeneration in intensively preserved woods before returning to Bouillon and dispersing.

The Belgians were wonderful hosts and proved that they are advanced foresters in the management of plantations and their conversion to forests. The clash of game and forest interests was, however, noticeable. Private owners present had much admiration for the work of state foresters. This admiration is shared by your representative, who is more than ever sure that a visit to the Belgian forests will prove of immense interest and profit to members of this society. Moreover, we are assured of a great welcome, by private as well as state foresters.

M. J. P.

A GUIDE TO THE NAMED VARIANTS OF SCOTS PINE (*PINUS SILVESTRIS* LINNAEUS)

By A. CARLISLE

(*Department of Forestry, University of Aberdeen*)

SUMMARY

The paper describes the meaning of 144 botanical terms used in the literature (111 references) concerning the geographical and morphological variants of Scots pine. Where the author has examined fresh material, comment is made upon the status of the variants.

IN the Scots pine literature, botanical terms are frequently used when referring to morphological variants of the species, and more often than not these terms are meaningless to the reader. Descriptions of the variants are difficult to find in the vast literature, and it is the purpose of this article to describe the majority of them, giving references to more detailed descriptions where possible. Where the author has examined fresh specimens comment will be made upon the status of the variant.

Where the prefix 'variety' (var.) or 'form' (f.) is given in the literature, the author's term will be used; where there is doubt, the term will be bracketed. If a variant is described without comment, it does not necessarily mean that it is valid, as this can only be assessed by studying representative samples and progeny trials.

GEOGRAPHICAL VARIANTS

The geographical varieties or sub-species refer to populations which grow in particular geographic regions and have characteristic morphological features. Little is known about the overall distribution of individual Scots pine variants, and it is therefore difficult to assess whether or not the pine from any one region is sufficiently distinct to warrant the designation of a geographical variety. Geographical varieties of Scots pine are, unless the population is so small as to be insignificant, essentially heterogeneous in their morphology, and contain a wide range of habit, bark, leaf, and cone variants, as well as physiological variants about which little is known. The geographical varieties differ in their morphology, but they differ rather in the frequency with which certain variants occur than in the striking absence or occurrence of any one variant. It is quite erroneous to assume that a particular geographical variety of Scots pine refers to a *single* morphological type. As an example, var. (ssp.) *lapponica* (2) is often regarded as a narrow-crowned variety. It is quite true that there are more narrow crowns in this geographical variety than var. *scotica* (1) or var. *septentrionalis* (3), but by no means all var. (ssp.) *lapponica* trees have narrow crowns, and the narrow-crown

form is not entirely absent from var. *scotica* or var. *septentrionalis*. The essential morphological difference is one of relative frequency of the variants.

1. var. *scotica* Schott

The indigenous Scots pine of Scotland (Carlisle, 1954) occurring naturally within the limits of latitude 57° 57′ N. to 56° 22′ N. and longitude 2° 53′ W. to 5° 38′ W., ranging from sea-level to 2,050 feet (615 m.) above mean sea-level.

Habit: generally var. *horizontalis* (27), f. *ascensa* (28) and intermediate forms. F. *condensata* (30), f. *fastigiata* (29), f. *pyramidalis* (31), and f. *pendula* (38) are present but less common. Very narrow crowns are rare. *Bud*: red brown, rarely bright red. *Leaf*: generally grey-green, frequently glaucous, in the first summer; winter colour dark grey-green, rarely yellowish; mean length 44 mm., width 1·6 mm.; persist 2 to 5 years, mean 3 to 4 years; generally slightly twisted, rarely very twisted as in var. *spiralis* (78); mean number of cotyledons 5, length 19·2 mm. *Timber*: all trees have red heartwood when more than 100 years old. *Cone*: 42·4 per cent. f. *plana* (81), 39·9 f. *gibba* (82), and 17·7 f. (var.) *reflexa* (83); mean length 3·8 cm.; generally grey-brown or grey-green-brown, sometimes cinnamon-brown and yellowish. *Seed*: mean weight 4·96 g. per 1,000 seeds; mean length 4·2 mm.; pale grey-brown to nearly black, sometimes mottled; seed-wings pale brown to dark red-brown, striped or unstriped, long and narrow to short and broad. *Male flowers*: generally yellow or pink-yellow, sometimes bright violet- or purple-red (f. *erythranthera*, 90). *Pollen*: mean grain body width 43·5 μ, length 38·2 μ; mean air-sac length 33·7 μ. *Synonyms*: (var.) *rubra* Grigor (59), (var.) *scotica* Willdenow (1), (var.) *montana* Sang (62).

The available data suggest that var. *scotica* resembles the pine of southern Sweden and differs from that of northern Sweden in the scarcity of narrow crowns, the leaf dimensions, leaf persistence, number and length of cotyledons, percentages of the cone colour variants, and mean length of the pollen grain air-sac.

2. var. (ssp.) *lapponica* Fries

The Scots pine of northern Scandinavia (Neger, 1913). It persists as far north as 70° N. and merges southwards into var. *septentrionalis* (3).

Habit: variable, but includes a higher proportion of narrow-crown types with branches persisting low down the stem than var. *scotica* (1) and var. *septentrionalis* (3) (Carlisle, 1954; Sylven, 1916). *Leaf*: grey-green but not as glaucous as var. *scotica* (1) in the first summer; often yellowish or violet in winter; short and wide; persist 4 to 7 years; mean number of cotyledons 4 to 5, length 10 mm. (Bailey, 1933; Holmerz, 1888). *Cone*: 69·2 per cent. f. *plana* (81), 21·5 f. *gibba* (82), and 9·2 f. (var.) *reflexa* (83); mean length 3·0 to 4·0 cm.; generally straw-yellow or brownish yellow, with or without brown-violet (Sylven, 1916). *Seed*: weight 2 to 3 g. per 1,000; generally brown-yellow, frequently black to dark brown, rarely bright yellowish white; seed-wings generally yellowish red-brown, frequently red-brown, rarely violet-brown; wings long and narrow to short and broad. *Pollen*: mean air-sac length 37·13 μ (Linquist, 1935; Schott, 1907; Schotte, 1905; Sylven, 1916). *Synonyms*: *Pinus lapponica* Mayr; *P. frieseana* Ascherson; *P. silvestris frieseana* Caspary (Wichura).

This geographical variety differs from var. *scotica* (1) and var. *septentrionalis* (3) in many characters such as crown form, leaf persistence, cone colour, &c. It was suggested at one time that it should be called *P. lapponica* and elevated to specific status (Mayr, 1906), but

this was not generally accepted. Var. (ssp.) *lapponica* is said to resemble var. *engadinensis* (11), particularly in its habit, and it has been suggested that the two are synonyms, but Rubner is probably correct in his assertion that they are distinct but parallel types (Beissner, 1891, 1909; Christ, 1883, 1907; Rubner, 1934; Willkomm, 1887).

3. var. *septentrionalis* Schott

The Scots pine of middle, southern, and south-western Scandinavia, extending into northern Germany and western Russia. Its northern limits merge into var. (ssp.) *lapponica* (2).

Habit: variable, with more of the broad crowns with branches persisting a short way down the stem than var. (ssp.) *lapponica* (2), and fewer narrow crowns than the latter. The var. *septentrionalis* population, however, includes some narrow-crowned types with branches persisting low down the stem, especially in eastern localities (Lindquist, 1935; Nordmark, 1950; Sylven, 1916). F. *condensata* (30) occurs within the boundaries of this geographical variety (Arnborg, 1941, 1946*a*, 1946*b*). *Leaf*: grey-green; mean length 35 to 43 mm.; persistence 3 to 6 years, mean 3 to 4 years; number of cotyledons 4 to 7, mean 5 to 6, length up to 26 mm. (Holmerz, 1888). *Cone*: f. *plana* (81) most common, f. *gibba* (82) frequently, f. (var.) *reflexa* (83) rare; mean length 3·5 to 4·0 cm. with cones longer than 4·0 cm. more common than in var. (ssp.) *lapponica* (2); generally grey-brown-green (Sylven, 1916). *Seed*: Generally black to dark brown, frequently brown-yellow, rarely bright yellow-white, the darker seeds being more common than in var. (ssp.) *lapponica* (2); seed-wings generally violet-brown, frequently red-brown and yellowish red-brown (Sylven, 1916). *Pollen*: mean air-sac length of pollen from trees with broad crowns 33·66 μ and with narrow crowns 37·84 μ (Lindquist, 1935).

Schott (1907) regards var. *septentrionalis* as intermediate between var. (ssp.) *lapponica* (2) from northern Sweden and var. *borussica* (5) of the north German lowlands. It also resembles var. *scotica* (1) and differs from var. (ssp.) *lapponica* (2) in the scarcity of narrow crowns, and its leaf dimensions, leaf persistence, cotyledon number and length, its cone colour variants, and the pollen grain air-sac length (Carlisle, 1954).

4. var. *rigensis* Loudon (Fischer?)

The Scots pine from the vicinity of the Gulf of Riga, merging into var. *septentrionalis* (3) at its boundaries. The trees often have perfectly straight stems with a regular, pyramidal, or lance-shaped crown and slender, ascending branches. Chatin (1865) states that it has pronounced reddish-yellow bark down to about 1 to 2 m. above the soil; pale green shoots; yellowish to reddish buds; leaves without a pronounced glaucous sheen; and cones which are small, generally grey, but sometimes with a violet tinge, generally have a slightly raised apophysis. The seedlings have about 6 (4 to 7) cotyledons. The type was highly valued in the eighteenth and nineteenth centuries for ships' masts (Elwes, 1908; Loudon, 1938; Rehder, 1940; Seitz, 1927; Sivers, 1903). Some authors regard it as synonymous with var. *septentrionalis* (3) (Münch, 1924; Schott, 1907), but it is generally regarded as a separate geographical variety (Bailey, 1933; Baldwin, 1933; Butts, 1940; Rehder, 1940; Seitz, 1927; Willkomm, 1887). Synonymous with *P. rigensis* Desf.

5. var. *borussica* Schott

Occurs in the north-east German lowlands. Münch (1924) describes it as having straight stems, medium branch development, a crown whose form is between that of var. *superrhenana* (7) and var. *hercynica* (9), and vigorous growth. Within the variety heavy branch forms predominate in southern and middle localities, with slender crowns more common in

northern and eastern districts. Schott (1907) regards it as the optimal pine of Germany. It is long lived, and produces violet-green to golden-brown cones with blackish-brown seed, often mottled, and grey-violet seed-wings.

6. var. *batava* Schott

Occurs in the lower Rhine districts. Its habit is intermediate between var. *borussica* (5) and var. *superrhenana* (7). The needles are long and although the tree does not live as long as var. *borussica* (5), it grows rapidly and matures early (Schott, 1907).

7. var. *superrhenana* Schott

Occurs in the upper Rhine districts. Its habit is intermediate between that of var. *batava* (6), var. *borussica* (5), and var. *vindelica* (8). The stem form is inferior to that of var. *borussica* (5), but it produces a larger volume per tree. The branches are often horizontally disposed and bear dense, luxuriant blue-green foliage. The seeds are large. Sometimes regarded as synonymous with var. *haguenensis* (10) (Schott, 1907).

8. var. *vindelica* Schott

Occurs in the northern Pre-Alp region, in northern Switzerland, and Austria. It has a straighter stem than var. *superrhenana* (7) and short leaves, but the habit is not as straight and regular as that of the northern pines (Schott, 1907).

9. var. *hercynica* Münch

Occurs on the southern and mid-German mountains; to 3,330 feet (1,000 m.) in the Schwarzwald and to more than 2,100 to 2,400 feet (630 to 720 m.) in mid-Germany. The stem is very straight and the crown narrow and pointed, with slender, flexible branches. In lower situations the stem remains straight, but the narrow, pointed crown is less marked. It forms valuable stands. A somewhat similar type occurs in north-eastern Germany, but var. *hercynica* is quite different from var. *superrhenana* (7) (Münch, 1924).

10. var. *haguenensis* Loudon

Occurs in the Hagenau and Rastadt forests on both sides of the Rhine. Loudon (1838) describes the trees as tall, straight, and clean, with smooth reddish bark when old. When the trees are young they have reddish, resinous buds, and long, twisted, light green, slightly glaucous leaves. The young plants grow rapidly. The status of this race is confused. Münch (1924) and Schott (1907) regard it as synonymous with var. *superrhenana* (7), but Loudon's description (1838) is quite different from Schott's var. *superrhenana* (7). Murray (1920) states that var. *haguenensis* breeds true for its characters when grown from seed. It may be regarded as a silviculturally desirable type of Scots pine whose taxonomic status is in doubt.

11. var. *engadinensis* Heer.

The Scots pine of the Engadine Alps, parts of Switzerland, and the Tyrol, where it grows up to 6,000 feet (1,800 m.) above mean sea-level. The trees are generally small, up to about 50 feet (15 m.) high, with slender crowns and branches persisting low down the stem, a habit comparable to that of var. *lapponica* (2); others have pyramidal crowns and some old trees have 'umbrella' crowns. The bark is yellow or reddish, and the leaves short (less than 3·5 cm.), thick, stiff, acute, grey-green, and persistent for 4 to 8 years. The cones are small, often pale yellow, ovoid-conic, and with a convex apophysis bearing a large blunt

umbo. Descriptions by different authors vary slightly (Bailey, 1933; Bean, 1951; Beissner, 1891; Elwes, 1908; Heer, 1862; Rehder, 1940; Rubner, 1934, 1953). It has been suggested that var. *engadinensis* Heer is synonymous with var. (ssp.) *lapponica* (2) (Christ, 1883; Willkomm, 1887).

Narrow-crown forms with branches persisting low down the stem occur frequently both in northern and mountain districts throughout Europe, so that the habit of Scots pine from a northern region may resemble that from a mountain district in a completely different geographical region. It is quite erroneous to regard two geographical varieties as synonymous because they have a similarity in habit.

12. (var.) *aquitana* Schott

Occurs in the Massif Centrale of southern France. The trees have rather open foliage with short, deep green leaves (Schott, 1907). It flowers comparatively early and produces small black seeds often with violet wings (Beissner, 1891).

13. (var.?) *subillyricum* (Corona?)

Corona (1955) uses the term *P. silvestris subillyricum* when referring to the Scots pine of the Trentino province of Italy.

14. (var.) *pannonica* Schott

The Scots pine of the hill country of western Hungary. It resembles var. *superrhenana* (7) in its habit, flowers profusely, and bears cones of the f. *plana* (81), f. *gibba* (82), and f. (var.) *reflexa* (83) types with black seed which, although small, germinates well (Schott, 1907).

15. var. *nevadensis* Christ

The Scots pine growing in the Sierra Nevada of southern Spain at a latitude of about 37° N., where it grows up to an elevation of 8,000 feet (2,400 m.). This is the southernmost station of naturally grown Scots pine (Rubner, 1953; Vazquez, 1947). Little is known about its morphology, but it is reported to be of poor timber form (Schreiner, 1956) with short, broad, stiff leaves which are very white on the flat adaxial surface, and cones which are nearly sessile and reddish grey in colour with a high, pyramidal apophysis (Beissner, 1891; Elwes, 1908). Schreiner (1956) has described the Scots pine of Spain generally, and it includes excellent straight, clean-boled stems, so var. *nevadensis* is not representative of the Scots pine of Spain as a whole. It can be regarded as a local geographical variety.

16. (var.) *armena* (Beissner?)

Occurs in the Caucasus, Asia Minor, and the Crimea. The leaves are glossy green, acute, and densely cover the branches. The cones are borne on short stalks, grow upwards or horizontally, are shining yellow-brown when ripe, and usually have raised apophyses (Beissner, 1930). Probably synonymous with var. *armena* Koch, *P. armena* Koch, *P. kochiana* Klotzsch, *P. silvestris* ssp. *kochiana* Klotzsch, and *P. pontica* Koch (Elwes, 1908; Sukatchev, 1938).

17. var. *altaica* Ledebour

Occurs on the Altai mountains of Russia. A tree about 50 feet (15 m.) high with a compact pyramidal crown and short leaves (Gordon, 1858, Hooper, 1868). Possibly synonymous with (var.) *sibirica* (21).

In addition to these geographical varieties there are several varieties mentioned in the literature, particularly in Russian works, about which little is known except that they occur in certain geographical regions, and it is difficult to tell if they are true geographical varieties. However, they will be classed as such for convenience in this paper until more is known about them. The position is made even more confusing by the practice of some recent Russian authors of elevating Scots pine from a particular region to specific status, calling, for example, the Scots pine of the Caucasus *P. caucasica* Busch, and of Armenia *P. armena* Koch (Galpern, 1949).

18. (var.) *caucasica* (Busch?)

Occurs in the Caucasus mountains (Galpern, 1949). Synonymous with *P. caucasica* Busch.

19. (var.) *altissima* (Loudon?)

Occurs in the Caucasus (Loudon, 1838). Probably synonymous with var. *caucasica* (18).

20. (var.) *uralensis* Fischer

Occurs on the Ural mountains of Russia and has short, stiff leaves (Elwes, 1908).

21. (var.) *sibirica* Ledebour

A geographical variety which forms woods at the foot of the Altai mountains, where it ascends to about 3,000 feet (900 m.), and in the desert regions of Sungaria and Kirghiz in Russia. It has short leaves and cones with numerous scales, some being flattened and others bearing a prominent, pyramidal apophysis (Ledebour, 1833). Probably synonymous with var. *altaica* (17) (Komarov, 1934; Ledebour, 1833; Sukatchev, 1938).

22. (var.) *jacutensis* Sukacz

23. (var.) *annulata* Jurinson

Two Scots pine variants mentioned by Kruberg (1937) as growing in eastern Siberia.

24. (var.) *funebris* (Kom.?)

25. (var.) *mongolica* (?)

Occur in Manchuria. Mentioned by Kruberg (1937) and Campo-Duplan (1950).

26. (var.) *cretacea* Kalenicz

Occurs in Russia on calcareous sites (Grozdov, 1945; Komarov, 1934).

Habit variants

27. var. *horizontalis* Don

A tree with a straight stem, a regular cylindric-conic crown, and slender branches which are horizontal in the middle third of the crown, but tend to ascend at the top and droop at the base. It grows to a height of 90 feet (27 m.) or more. The foliage is generally grey-green, and sparse to moderately dense giving the crown a rather open appearance. The type is abundant throughout the native Scottish pinewoods and, although there is some indication that it is not as fast growing as f. *ascensa* (28), its crown and stem form are desirable

from a silvicultural point of view. It is not confined to Scotland, and the author has seen trees closely resembling var. *horizontalis* in both western Norway and the Ligurian Appenines of Italy. There is little doubt that it is genetically controlled, and trees intermediate between var. *horizontalis* and *f. ascensa* (28) predominate in many woods (Carlisle, 1954; Don, 1814). The original claims by Don that this habit was correlated with comparatively smooth bark and smooth thick cones has not been supported by recent investigations (Carlisle, 1954).

28. f. *ascensa* Carlisle

A tree with a cylindric-conic but often irregular crown. The stem is generally free from forking, but its straightness is more variable than that of var. *horizontalis* (27). The branches are often coarse, ascending in the upper two thirds of the crown, but sometimes horizontal or even pendulous at the crown base. It is a vigorous tree and appears to grow more rapidly than var. *horizontalis* (27). The foliage is appreciably denser than that of var. *horizontalis* (27), and coloured grey-green. The available evidence indicates that it is genetically controlled. Intermediates between f. *ascensa* and var. *horizontalis* (27) predominate in some Scottish woods (Carlisle, 1954).

29*a*. f. *fastigiata* Carrière

A tree up to 60 feet (18 m.) high with a columnar crown, vigorous strictly fastigiate branches, and dense bluish-green foliage. The cones are small or of moderate size, with raised apophyses. Its distribution is not fully known, but it has been recorded in Pomerania (Carrière, 1867; Schwerin, 1906) and Scotland (Carlisle, 1954), and is used in gardens both in Britain and the U.S.A. (Slavin, 1932; Veitch, 1900). It appears to be genetically controlled.

29*b*. f. *fastigiata glauca* hort. with glaucous leaves is mentioned in the literature (Schelle, 1920). No details are known.

30. f. *condensata* Fries (Arnborg)

Commonly known in Scandinavia as the 'kvastall' or 'busktall' (mop-pine or bushy pine). It has a dense bushy crown consisting of numerous coarse, strongly fastigiate branches rising almost from ground level when the tree is young. There is no true main stem, the vertical axis of the tree consisting of the fastigiate or almost vertical branches which, as the tree grows older, become closely adpressed or even fused to form a compound 'stem' which is often convoluted. The tree bears only a few small cones, and has no distinctive characters of cone and leaf. Arnborg found that 12 per cent. of the progeny of these trees had multiple 'stems' and the character seems to be genetically controlled. It occurs naturally in the Malar region in eastern middle Sweden and in Scotland (Arnborg, 1941, 1946*a*, 1946*b*; Carlisle, 1954; Fries, 1890).

31*a*. *pyramidalis* (Elwes and Henry)

A tree with a pyramidal crown and fastigiate branches occurring in Russia, Norway, Finland, and Scotland (Carlisle, 1954; Elwes, 1908). Some authorities regard it as synonymous with f. *fastigiata* (29) and f. *watereri* (33). Its genetic status is not known.

31*b*. (f.) *pyramidalis glauca* hort. has very blue-green leaves, but is apt to revert to the normal type (Beissner, 1909).

31*c*. (f.) *pyramidalis compacta* Hornibrook. A dwarf type (about 3 feet or 0·9 m. high),

with fastigiate but only few branches, and of very slow growth. Buds very resinous and red-brown. Leaves wide and 1·9 to 3·8 cm. long, shining dark green, closely crowded, and incurving towards the branchlets. Originating in the nurseries of Simon-Louis, Frères of Metz (Beissner, 1930; Hornibrook, 1923).

32*a*. (f.) *columnaris* Croux

A horticultural variety with a columnar crown (Croux, 1889).

32*b*. (f.) *columnaris compacta* Croux. A dwarf form bred in French nurseries, it is seldom more than a few metres in height and has short, erect branches with 4 to 5 cm. long, glossy, dark-green leaves with little or no blue sheen (Beissner, 1891; Croux, 1889).

33. f. *watereri* Beissner

A semi-dwarf type with a broadly columnar or pyramidal crown and ascending branches bearing dense steel-blue foliage, the leaves being 4 to 6 cm. long (Beissner, 1902; Bailey, 1933; Rehder, 1940). It has achieved some popularity as an ornamental tree in northern America. It is sometimes regarded as synonymous with f. *fastigiata* (29), but this is doubtful, as the latter is not necessarily a semi-dwarf tree.

34. (var.) *compressa* Carrière

A fastigiate, slow growing horticultural variety resembling f. *fastigiata* (29) but with the branches even more erect than the latter. The crown is narrow with comparatively few branches, these being strictly fastigiate and closely applied to the tree trunk. The buds are small, light brown, and non-resinous, while the short (to 3·8 cm.), blue-green, stiff leaves are densely crowded and adpressed to the branchlet. The cones, which are small, slightly elongated and slightly curved, have well developed apophyses which are often recurved, cf. f. (var.) *reflexa* (83), at the base of the cone (Carrière, 1867; Hornibrook, 1938). The habit and leaf colour resemble that of f. *watereri* (33).

35. (f.) *erecta* (Mouillefert)

A type with a slender stem, more or less erect branches, and ochre coloured bark persisting low down the stem. The leaves are long and glaucous, but have little or no twist. It is one of the better types of Scots pine (Mouillefert, 1892–8). Mouillefert regards it as synonymous with var. *rigensis* (4), but it is probably more correct to say that it is a habit variant which occurs within the latter geographical variety (4), and probably others.

36. (var.) *intermedia* Loudon

A tree with slender shoots depressed towards the stem and short leaves which are less glaucous than is usual in Scots pine. Occurs in Russia, and has been grown in gardens in Britain (Loudon, 1838; Hooper, 1868).

37. (var.) *plicata* Schenk

A dwarf bush, about 3 m. high, with fastigiate branches and a rounded bushy crown. Occurs in Germany (Beissner, 1930; Schenk, 1925).

38. f. *pendula* Caspary

Known as the 'Trauerkiefer' or weeping Scots pine. It has distinctly pendulous branches and is quite common in the pine forests of Europe (Beissner, 1930; Caspary, 1866; Dallimore, 1954; Elwes, 1908; Pardé, 1937). In Scotland it appears to be genetically controlled

and has two crown forms, cylindrical and dome-shaped (Carlisle, 1954). Sometimes used in horticulture (Bailey, 1933).

39. f. *virgata* Caspary

The 'Schlangenkiefer' (snake pine), 'Rutenkiefer' (virgate pine), or 'Ormtall' (worm pine). A small tree less than 40 feet (12 m.) high with the branches of the first order arising singly or in very irregular whorls. No branches of the second order are produced for several years, but eventually there is a branching of the lower shoots to the sixth order, and the branches make an angle of 30 to 60 degrees with the stem. The tree bears cones of the f. *plana* (81) type. It has been recorded in north-east Germany, France, and Sweden (Beissner, 1930; Caspary 1822–3; Elwes, 1908; Schwerin, 1906; Sylven, 1910). Generally regarded as a genotype.

40. (f.) *anguina* hort.

A horticultural variety with a twisted stem, branches growing in all directions, bluish leaves and 4-cm.-long cones with flat apophyses (Beissner, 1899, 1930).

41. (f.) *tortuosa* Büttner

The 'Drehkiefer' or twist pine. A tree with twisted stem and branches (Büttner, 1897). Probably synonymous with (f.) *anguina* (40).

42. (f.) *nana* Carrière

A dwarf, 20-inch (50 cm.) high bush with numerous short, thin, erect, straggling branches. The leaves are about 3·0 cm. long, straight, glaucous, and set far apart on the shoot. Cones small, about 2 cm. long. It resembles, but is smaller than, (f.) *globosa* (43), and is grown in gardens in Britain and the U.S.A. (Bean, 1951; Carrière, 1851, 1867; Dallimore, 1954). Sometimes regarded as synonymous with (f.) *pygmaea* (44), and is probably the same as var. *nana* Pall mentioned by Komarov (1934). Appears to be genetically controlled.

43*a*. (f.) *globosa* hort.

A dwarf, low, dense, rounded shrub, not quite as dwarfed as (f.) *nana* (42). A specimen in Herefordshire, Britain, in 1932 was 2 feet 2 inches (0·7 m.) high, with a branch spread of 1 foot 10 inches (0·6 m.). The leaves are about 2·5 cm. long, and the cones 1·8 cm. long (Bean, 1951; Conifers in Cultivation, 1932; Dallimore, 1954; Pardé, 1937).

43*b*. (f.) *globosa viridis* hort. A dwarf with bright-green leaves (Beissner, 1930).

43*c*. (f.) *globosa nana* hort. resembles (f.) *nana* (42) and generally refers collectively to (f.) *nana* (42) and (f.) *globosa* (43) (Beissner, 1891). Sometimes regarded as synonymous with (f.) *pygmaea* (44).

44. (f.) *pygmaea* hort.

This term is often used rather loosely in referring to dwarf Scots pine in general and is sometimes regarded as synonymous with (f.) *nana* (42), (f.) *globosa* (43), and (f.) *saxatilis* (46) (Beissner, 1891, 1909, 1930; Carrière, 1867). Horticulturists sometimes prefer a finer distinction, and Hornibrook (1938) describes (f.) *pygmaea* as a dense, round bush of slow growth, 3 to 3·5 feet (0·9 to 1·4 m.) high, with red, resinous, oval buds and crowded, red branches bearing 0·5 to 1·0 inch (1·3 to 2·5 cm.) long, thick, stiff, very twisted leaves which are not as glaucous as those of f. *pumila* (45).

45. (f.) *pumila* Beissner

An open, rounded bush with ascending branches and red resinous buds. The leaves are blue-green, 2·5 to 3·8 cm. long, stiff, and twisted, while the cones are small, 1·9 cm. long. (Bailey, 1933; Bean, 1951; Beissner, 1891, 1909, 1930; Hornibrook, 1938; Pardé, 1937). Synonymous with (f.) *glauca* hort. (Beissner, 1930). Not to be confused with *P. silvestris* (f.) *pumilio*, an obsolete term for *P. mugo* var. *pumilio* (Dallimore, 1954).

46. (f.) *saxatilis* Carrière

A prostrate, spreading shrub with no definite trunk, consisting of numerous, slender branches bearing short leaves 12 to 25 mm. in length. It spreads on the ground like a mat, one garden specimen brought from Geneva and grown in Essex, Britain, being 6 inches (15·2 cm.) high and 4 feet (1·2 m.) across at an age of 40 years in 1938. It is a delicate plant. (Carrière, 1867; Hornibrook, 1938). Sometimes included in the collective term (f.) *pygmaea* (44).

47. (var.) *genevensis* Beissner

A low growing, dwarfed, crooked shrub with numerous twisted, spreading branches, and very small, dark crimson-brown buds. The leaves are 1·9 to 3·8 cm. long, thin, flexible, and produced in small tufts at the ends of the branchlets. A horticultural curiosity believed to have originated in nurseries at Metz (Beissner, 1909, 1930; Hornibrook, 1938). It should not be confused with (var.) *genevensis* Bauhin (92) about which little is known, but which probably refers to the 'common' or 'ordinary' Scots pine of Europe.

48. (var.) *umbraculifera* Beissner

A dwarf, rounded, broad bush of open growth with few, spreading, slightly ascending branches and 3·8 to 7·6 cm. long leaves (Beissner, 1891, 1909, 1930; Hornibrook, 1938).

49. (f.) *beauvronensis* hort.

A dwarf, dense, much-branched bush which only attains a height of about 1·7 feet (0·5 m.) in 25 years, and resembles the 'Witch's Broom' of Scots pine. It has small, resinous, dark-red buds, and leaves only 1·3 cm. long with a relatively long (0·6 cm.) pale coloured leaf-sheath. It originated in the nurseries of Transon Frères at Beauvronne in France. Occasionally grown in British gardens (Bean, 1951; Beissner, 1891, 1930; Hornibrook, 1938).

50. (f.) *turfosa* Woerlein

A dwarf, 1·7 to 6·7 feet (0·5 to 2·0 m.) high shrub with a straight, erect central shoot, forming a small, flat crown later in life. The short (25 mm.) needles are curved and often fall in the second year. It produces numerous small cones with well developed seed. The type occurs on bogs in north-west Germany and along the Baltic coast. Synonymous with *P. turfosa* Willkomm (Beissner, 1930; Woerlein, 1893), and possibly with var. *nana* Pall (Sukatchev, 1938).

51. (f.) *katakeimenos* Graebner

A dwarf form with prostrate stems and branches up to 50 cm. long, but not raised more than 7 feet (2·1 m.) above the ground. The young shoots are very long and slender, and bear normal leaves and cones. It occurs on sand dunes on the Baltic coast, in Sweden, and northern Russia (Beissner, 1930).

Bark variants

52. (var.) *seitzii* Schwerin

The bark units consist of thin, smooth, more or less isodiametric, light-coloured plates, separated by narrow, shallow fissures. The bark superficially resembles the shell of a turtle. Generally known as the 'Plattenkiefer', or plate bark pine (Carlisle, 1954; François, 1947; Seitz, D., 1926, 1927; Seitz, W., 1927). Seitz (1929–38) claimed that in Germany this bark is correlated with a stem which tends to fork, laterally extensive branches, scanty yellow-green foliage, cones whose apophyses are not very prominent, a broad heartwood dark pink in colour when dry, and timber with uniform grain and low resin content.

53. (var.) *kienitzii* Seitz

The bark is in the form of thick, dark coloured, coarse, elongated, overlapping scales or ridges, separated by deep fissures. Generally known as the 'Schuppenkiefer', scale bark or ridge bark pine (Carlisle, 1954; François, 1947; Seitz, 1926, 1927, 1929–38). Seitz (1929–38) claimed that this bark was correlated with a dense, conical crown, with a persistent stem, branches which are shorter than those of (var.) *seitzii* (52), dark green rigid leaves, an elongated cone with a prominent apophysis, a narrow heartwood dark red in colour when dry, and resinous timber with a coarser grain than that of var. *seitzii* (52).

54. (var.) *bonapartei* Seitz.

The bark is in the form of small, more or less isodiametric, concave, thin, brown scales. Generally known as the 'Muschelkiefer', mussel bark, or flake bark Scots pine (Carlisle, 1954; François, 1947; Seitz, 1929–38). Seitz (1929–38) claimed that the bark type was correlated with an extremely narrow, pointed crown with a straight stem, short flexible branches, blue-green leaves, cones the same as var. *seitzii* (52), and timber with a long, fine grain.

The genetic status and significance of these bark types has been the subject of much discussion (Hejmánek, 1953; Dengler, 1938; 1944; Seitz, 1929–38). The author (Carlisle, 1954) found, however, that in Scotland there are two distinct bark series; firstly, trees with the ridge bark of (var.) *kienitzii* (53) develop the plate bark of (var.) *seitzii* (52) as they reach maturity; secondly, trees with the flake bark of (var.) *bonapartei* (54) develop a plate-flake bark intermediate between that of (var.) *kienitzii* (53) and (var.) *bonapartei* (54) as they grow old. No correlation of the bark type with the other characters suggested by Seitz (1929–38) was found. It would seem, therefore, that the three bark variants described by Seitz, vars. *seitzii*, *kienitzii*, and *bonapartei*, refer only to parts of two separate developmental series, and as such cannot be regarded as valid varieties. If it is wished to distinguish these Scots pine bark unit variations by botanical nomenclature, the terms should refer to the separate bark development series.

55. (f.) *annulata* Fintelmann (Caspary)

The 'Schindelkiefer' or 'shingle pine'. The bark scales in the lower part of the stem are distributed in rings, with a ring-like fissure extending laterally around the stem near the former position of the old branch whorls, the bark scales overlapping like the shingles on a roof. It is comparatively rare, but has been recorded in Germany, and near Lake Constance on the German–Austrian–Swiss border (Beissner, 1911, 1930; Caspary, 1882–3; Fintelmann, 1881). It may be the same as (var.) *annulata* Jurinson (23) of Russia, but no details of the latter are available.

56. (f.) *gibberosa* Kihlman

A type known as the 'Knollenkiefer', with numerous humps on the bark surface. Occurs in Germany (Beissner, 1906, 1911, 1930; Kihlman, 1906; Pardé, 1937).

57. f. *sigillita pilsudskiana* Stecki

A rare type occurring in Poland, with deep indentations in the bark arranged in regular (5/13) parastichies, both on the stem and shoots. The annual rings undulate. It does not appear to be due to pathological causes (Stecki, 1937).

58. (f.) *laevigata* Schwerin

A bark variant in which the thin yellow-brown upper bark covers most of the stem, with little (up to 30 cm.) or no rough, fissured, dark-coloured bark at the base of the tree. Occurs in Germany (Schwerin, 1911).

59. (var.) *rubra* hort.

A type with reddish bark. Carrière (1867) describes it as reaching 100 feet (30 m.) in height and having a conical crown; very glaucous, often twisted, 4 to 8 cm. long leaves; 4 to 6 cm. long cones with the apophyses raised, obtuse, and often recurved at the cone base. It is not generally regarded as a valid variety, and is thought to be synonymous with (f.) *latifolia* (68), (var.) *hamata* (84), var. *rigensis* (4), and *P. rubra* Willkomm (Beissner, 1891; Carrière, 1867).

The term (var.) *rubra* has been used in other senses: (var.) *rubra* Grigor (Gilchrist, 1871; Gordon, 1858), an obsolete term for the pine of Scotland; (var.) *rubra* Endl., a synonym for var. *superrhenana* (7) (Schott, 1907); and var. *rubra* Borkh. is mentioned by Mágocsy (1881) in Hungary.

Timber variants

60. (var.) *alba* Senilis

The 'White Scots pine', with creamy white timber. Habit variable, but the branches are more or less spreading and ascending. Bark rough and furrowed. Leaves 1 to 3 inches (2·5 to 5·1 cm.) long, coloured blue or greyish green. Cones 2 to 4 inches (5·1 to 10·1 cm.) long, egg-shaped, roundish, conical, or globular, scales straight or recurred. Seeds small with a relatively large wing. Senilis noted that this type predominated in both natural and planted woods on the continent of Europe (Senilis, 1866). It is not the same as var. *alba* hort. (76).

61. (var.) *rubra* Senilis

The 'Red Scots pine', with a yellowish-brown wood which, when grown on congenial soil, allowed to mature and seasoned, has a much darker, richer colour than (var.) *alba* (60). The branches are arranged horizontally, and the branchlets, although they tend to ascend when young, become horizontal as they mature. The tree often forms a rounded or umbrella crown on a trunk which is clean of branches for half to two-thirds of its length even when grown in isolation. The leaves are only 1 to 2 inches (2·5 to 5·1 cm.) long, and a slightly glaucous dark-green colour, much less glaucous than (var.) *alba* (60). The cones are only 1·5 to 2·0 inches (3·8 to 5·1 cm.) long, broader and less pointed than those of (var.) *alba* (60). This type is said to predominate in natural Scottish woods (Senilis, 1866). Not the same as var. *rubra* hort (59).

Neither of the terms var. *alba* (60) and var. *rubra* (61) are widely recognized. There is,

however, no evidence to disprove that they are genetically controlled variants, and there is a need for research on Scots pine timber variations.

62. (var.) *montana* Sang

An obsolete term referring to Scots pine yielding red, resinous timber even when young (Loudon, 1855). The term (var.) *montana* Matthiolus is mentioned by Loudon (1838) but no details are known.

Leaf variants

63. (var.) *microphylla* Schwerin

A tree with very short (10 to 15 mm.) leaves produced on slender branches (Beissner, 1930; Dallimore, 1954; Elwes, 1908; Schwerin, 1906). Beissner (1891) states that it breeds true and does not revert to type. Recorded in Germany.

64. (var.) *parvifolia* Heer

A tree with bluish leaves less than 25 mm. long, and small ovoid-conic cones with pointed tips and flat apophyses. Occurs in Lombardy, Rumania, Switzerland, and Sweden (Beissner, 1930; Czoppelt, 1938; Heer, 1862; Pardé, 1937; Rehder, 1940; Rosenbohm, 1882). Probably synonymous with (var.) *microphylla* (63).

65. (var.) *brachyphylla* Wittrock

Leaves very short (5 to 12 mm.) with only 2 to 3 resin canals per leaf. The stem is not necessarily stunted. Occurs in Finland (Beissner, 1906, 1930; Sylven, 1910). Probably synonymous with (var.) *microphylla* (63).

66. (var.) *brevifolia* Heer

A tree with a slender, conic crown and green, exceptionally short leaves. Occurs in Switzerland (Christ, 1883). Probably synonymous with (var.) *microphylla* (63), and (var.) *brevifolia* Rogov (Komarov, 1934).

67. (var.) *baenitzii* Baenitz (Tscherning)

A tree with very short leaves observed near Karlsbad in Austria (Tscherning, 1899). Probably synonymous with (var.) *microphylla* (63).

Most of these variants (63 to 67) could be conveniently grouped under the term var. *microphylla*.

68. var. *latifolia* Gordon

A variant with unusually broad, long, and glaucous leaves, the tree rapidly reaching a great size, and occurring in the Caucasus and the mountains near Erzerum, which Gordon states is in Persia but which is actually in north-east Turkey (Gordon, 1858, 1880; Hooper, 1868). Gordon (1858, 1880) regards it as synonymous with (var.) *persica* hort., *P. erzeroomica* Calvert, *P. caucasia* Fischer, and *P. altissima* Ledebour. It is probably a minor leaf variant within the geographical variety (var.) *caucasica* (18).

69. var. *divaricata* (Wahlenb.?)

A type with longer needles than usual growing at high altitudes. No details known (Beissner, 1930).

70*a*. var. *argentea* Steven

A well defined variant with silvery, glaucous-green leaves, the silvery sheen extending to the cones and persisting on the leaves even when they are dried. The tree is tall and vigorous with greyish-red bark, and bears cones with prominent hooked apophyses, *cf.* f. (var.) *reflexa* (83). It occurs naturally in the Caucasus of Russia, and is used as an ornamental tree in horticulture (Bailey, 1933; Bean, 1951; Beissner, 1891, 1909; Carrière, 1867; Dallimore, 1954; Elwes, 1908; Gordon, 1858, 1880; Hornibrook, 1938; Loudon, 1838; Rehder, 1940; Steven, 1938).

70*b*. (var.) *argentea compacta* hort. has silvery leaves and a rounded, compact crown form (Beissner, 1899).

71. var. *aurea* Beissner

A well defined variant with a dense globular crown and leaves which are golden yellow in autumn and winter, becoming green in the spring; these leaves undergo the seasonal colour variation two or three times before they fall (Bailey, 1933; Bean, 1951; Beissner, 1891, 1906, 1909; Webster, 1918). Used in horticulture.

72. (var.) *beissneriana* Schwerin

Resembles var. *aurea* (71), but the colour change differs in that the leaves are green in the summer and become golden green in the following spring. Used in horticulture, and recorded at Tharandt (Beissner, 1909, 1930; Schwerin, 1896, 1906).

73. (var.) *viridis compacta* hort.

A small, slow-growing tree with a narrow, conical open crown and grass-green leaves. Synonymous with (var.) *viridis compacta* Hornibrook (Beissner, 1930; Hornibrook, 1923, 1938).

74. (var.) *nivea* Schwerin

The leaves are almost milk white at first, greenish in summer, and later becoming a dirty, greenish white. Plants seen by Schwerin grew well at first, but died when transplanted (Beissner, 1909, 1930; Schwerin, 1906). Probably a chlorophyll mutant with a low survival value.

75. (var.) *variegata* Beissner

A variegated type with green leaves speckled white or creamy white, which has been seen growing in the forest beside Scots pine with normal foliage, suggesting that it is due to genetic rather than site factors. It occurs in Sweden, Germany, Jugoslavia, and in the arboretum at des Barres in France (Beissner, 1891, 1930; Degelius, 1943; Elwes, 1908; Omanović, 1937; Rol, 1954; Sylven, 1910).

76*a*. (var.) *alba* hort.

The Ghost Pine. This type, which is not the same as var. *alba* Senilis (60), refers to a tree with glaucous, pale foliage. It has been grown in Britain as an ornament, for example at Aldenham House at Elstree, where there was a 20 feet (6 m.) high specimen in 1932 (Conifers in Cultivation, 1932). No details known.

76*b*. (f.) *alba-spicata* Ouden is a shrub of slender habit and whitish leaves, which unfortunately suffers from the effects of insolation. It was grown in Holland from seed in 1924 and introduced to the horticultural trade in 1932 (Ouden, 1949).

77. (var.) *tortuosa* Don

A tree with short, twisted leaves (Beissner, 1930; Don, 1814). Not synonymous with (var.) *tortuosa* Büttner (41).

78. var. *spiralis* Carrière

A vigorous tree with large, twisted leaves, forming a 'crisp', confused foliage of attractive appearance. Tends to vary (Beissner, 1930; Carrière, 1867).

79. var. *crispata* Schwerin

A tree of rapid growth with long, curved leaves (Schwerin, 1906). Probably synonymous with (var.) *spiralis* (78).

80. var. *monophylla* Hodgins

Descriptions of this type vary as it seems that there has often been a confusion between plants suffering from leaf-fusion disease (Young, 1935, 1940) and the true (var.) *monophylla*. In the latter the two leaves in each bundle coalesce with each other, and are closely applied throughout their length to give the appearance of a single cylindrical leaf in each sheath, so that the foliage looks open and thin. In diseased leaves there is no actual leaf tissue coalescence (Ludbrook, 1937). The variant appears to be genetically controlled.

Cone variants

81. f. *plana* Christ

A cone type with an irregular, rather flat apophysis whose width is more than twice its height and which has a sharp lateral ridge. It occurs in Scotland, France, Germany, Switzerland, Sweden, west Hungary, and Russia. Many cones occur which are intermediate between f. *plana* (81), f. *gibba* (82), and f. (var.) *reflexa* (83) (Beissner, 1891, 1909, 1930; Caspary, 1882–3; Christ, 1864, 1865; Sylven, 1916). Synonymous with f. *plana* Heer and *P. plana* (Galpern?).

82. f. *gibba* Christ

A cone with a raised apophysis whose width is less than twice its height, and which has a broad, obtuse, lateral ridge, and appears broad and humped with more or less concave sides. It has been recorded in the same localities as f. *plana* (81). Cones intermediate between f. *gibba*, f. *plana*, and f. (var.) *reflexa* (83) are common (Beissner, 1891, 1909; Caspary 1882–3; Christ, 1864, 1865; Sylven, 1916). Synonymous with the f. *gibba* Heer mentioned by Willkomm (1887), and possibly with var. *echinata* Link, a type with a tapering cone and protruding pyramidal scales, occurring east of Lake Baikal and in the Amur region in Russia (Komarov, 1934).

83. f. (var.) *reflexa* Heer

A cone type with a prominent apophysis whose height may exceed its width and which is curved in the form of a hook, usually curving towards the cone base but sometimes towards the cone apex. It occurs naturally in Scotland, Germany, the valleys of the Swiss

Alps, Sweden, France, and Russia (Beissner, 1891, 1909; Caspary, 1882–3; Elwes, 1908; Heer, 1862; Murray, 1920; Sylven, 1916; Veitch, 1900).

Beissner (1891, 1909) stated that f. (var.) *reflexa* cones occur on trees of limited height, with irregular crowns, 6 cm. long leaves, and long, narrow cones with long peduncles. The author found, however, that in Scotland f. (var.) *reflexa* cones occur on trees with a wide range of habits and cone shapes. F. (var.) *reflexa* can only be regarded as a cone apophysis variant.

These three cone types are a convenient means of classifying Scots pine cone variants, but they by no means cover all the variations of cone apophysis and cone shape which occur within the species. There is little doubt that they are genetically controlled (Carlisle, 1954).

84. (var.) *hamata* Steven

A tree bearing long, acute cones with prominent hooked apophyses, long, narrow seed-wings, and leaves which are shorter than the cone. This type of Scots pine is of some importance in Russia where it is called *P. hamata* Steven (Sosnowsky). Galpern (1949) regards it as typical of central Russia, and it has also been recorded in the Caucasus, Germany, and the Tyrol (Beissner, 1891, 1930; Gams, 1930; Gulisašvili, 1951; Sokolowski, 1937; Steven, 1838; Sukatchev, 1938).

The author has examined specimens from the Caucasus and they are morphologically identical with the normal *Pinus silvestris* L. with f. (var.) *reflexa* (83) cones such as occurs in Scotland and other parts of Europe.

85. (var.) *uncinata* Don

A variety of Scots pine seen by Don (1814) in a Scottish plantation near Forfar. The tree bore cones with blunt, reflexed apophyses, and had a pyramidal crown with light coloured, glaucous leaves (Selby, 1842). Probably merely a cone variant synonymous with f. (var.) *reflexa* (83).

86. (var.) *macrocarpa* Schröder

A type with large cones two to three times the usual size and weight, and large seeds. Observed in the vicinity of Moscow (Beissner, 1894, 1930).

87. (var.) *scariosa* Loddiges

Loudon (1883) describes the cones of this type as having 'long scales, flat at the tips and bent back', but no details are known. It is native to the lower Alps, occurs in France and has been grown in gardens. Synonymous with *P. scariosa* (Loddiges ?). The description suggests a resemblance to f. (var.) *reflexa* (83).

88. (f.) *conis aggregatis* Syreitschikow

Clusters of 5 to 145 cones are produced on the main stem and, less often, on the side branches of this type in the middle of the season's growth instead of the end of the latter (anon. 1941; anon. 1942; Beissner, 1930; Kirchner, 1908; Pardé, 1937; Sorauer, 1909; Syreitschikow, 1906). The cones replace the normal two-leaf bundles and have the same 'phyllotaxy' as the bundles. It occurs in most large populations of Scots pine. The specimen seen by the author in Glen Feshie, Scotland, produced the cone clusters in three successive seasons, the first season's cones being normal 4·4 cm. long f. *plana* (81), those of the second season similar but smaller, and those of the third season stunted or partially aborted. This production of cone clusters is not confined to *P. silvestris* and, for example, Black (1957)

noted it on *P. contorta* Douglas. This unusual cone production appears to be a genetically controlled character occurring sporadically in some members of the genus *Pinus*.

89. (f.) *conglomerata* Carrière

Cone clusters produced as in (f.) *conis aggregatis* (88) (Carrière, 1867). Synonymous with the latter.

Male inflorescence variants

90. f. (var.) *erythranthera* Sanio

A type of Scots pine with male inflorescences which are violet-red, carmine, reddish or violet-brown just prior to anthesis. It occurs in most parts of Europe, and there are many intermediates between it and the more common yellow male flower. It appears to be genetically controlled (Beissner, 1891, 1909, 1930; Carlisle, 1954; Caspary, 1882–3; Elwes, 1908; Kirchner, 1908; Sanio 1871; Veitch, 1900). Synonymous with var. *rubriflora* Buchenau.

Beissner (1891, 1909) describes f. (var.) *erythranthera* as forming stands in Scotland of straight, tall, slender stems with red-brown bark and short, grey leaves. The author (Carlisle, 1954) found that the violet or reddish male inflorescences occurred on a wide range of habit, bark and leaf variants, and that there was no evidence of the correlations suggested by Beissner.

91. (var.) *monticola* Schröter

A tree producing a profusion of male flowers for eight or more successive years, and retaining the leaves for up to 8 years. The production of male flowers deprives the lower part of the shoots of foliage, the leaves being confined to the upper part of male shoots, giving the foliage a 'whorled' appearance. It occurs in Switzerland and North Germany (Beissner, 1930; Kirchner, 1908; Schröter, 1895). It is questionable whether or not the predominance of one sex in a tree is sufficient distinction to warrant the designation of a separate variety, even if the character is genetically controlled.

Seed variants

92. var. *melanosperma* Litvinov—with black seeds.

93. var. *leucosperma* Litvinov—with yellow seeds.

94. var. *baliosperma* Litvinov—with spotted seeds.

95. var. *phoeosperma* Litvinov—with chestnut-brown seeds.

These four Scots pine seed colour variants have been described in the Russian literature, but their significance is not known (Sukatchev, 1938). A similar range of seed colour variants occurs in indigenous Scottish pinewoods. The names of these variants are not in general use, but seed colour is probably genetically controlled to some extent.

96. There are also several terms used in the literature which refers to the 'ordinary' or 'common' Scots pine, although it is not always clear what is meant by 'ordinary'. Examples are (var.) *genuina* Heer (Caspary, 1882–3; Heer, 1862); (var.) *typica* (Nouv. Duham.?) (Turrill, 1948); (var.) *communis* Endl. (Carrière, 1867); (var.) *vulgaris* Clusius (Gordon, 1880); var. *vulgaris* Don (Don, 1814; Selby, 1842); (var.) *escarena* (?) (Gordon, 1880); and

(var.) *genevensis* Bauhin (Gordon, 1880). They can all be regarded as just *P. silvestris* L. Heer (1882–3) suggested that a type of pine in Switzerland may be a hybrid between *P. silvestris* L. and *P. montana* Du Roi, and called it *P. silvestris hybrida* (?) Heer, but this has not been confirmed.

97. There are some terms whose meanings have been lost, such as (var.) *europaea* (?); var. *austriaca* (?); (f.) *submontana* (Heer?) (Beissner, 1901, 1930); (var.) *tabulaeformis* Barron (Hornibrook, 1938); (var.) *pontica* Schröder (Beissner, 1898, 1896); (var.) *viminalis* Brenner; f. *sphagnicola* Willkomm (Komarov, 1934); and (var.) *cornigera* (Brenner?). When the original descriptions of these are traced it will probably be found that the majority are synonyms for some of the more generally recognized variants.

98. Finally, there are the misnomers, where varieties of other species have been erroneously regarded as varieties or forms of Scots pine. For example *P. silvestris* L. *humulis* Link, *rotundata* Link, *uliginosa* Link and *montana* Wahlbg. are all synonymous with *Pinus montana* var. *uncinata rotundata* Willkomm (Beissner, 1891, 1930); *Pinus silvestris bujotii* hort. is now called *Pinus nigra* var. *bujotii* (Beissner, 1930); and *Pinus silvestris maritima* Ait. is synonymous with *Pinus laricio* Poir (Beissner, 1891; Correvon, 1906).

Index to varieties and forms of Pinus silvestris *L.*

(Figures refer to numbers)

alba hort., 76*a*
alba Senilis, 60
alba spicata, 76*b*
altaica, 17
altissima, 19
anguina, 40
annulata Fintelmann, 55
annulata Jurinson, 23
aquitana, 12
argentea, 70*a*
argentea compacta, 70*b*
armena, 16
ascensa, 28
aurea, 71
(*austriaca*), 97
baenitzii, 67
balfosperma, 94
batava, 6
beauvronensis, 49
beissneriana, 72
bonapartei, 54
borussica, 5
brachyphylla, 65
brevifolia Heer, 66
brevifolia Rogov, 66
(*bujotii*), 98
caucasica, 18
columnaris, 32*a*
columnaris compacta, 32*b*
(*communis*), 92
compressa, 34
condensata, 30
conglomerata, 89
conis aggregatis, 88
(*cornigera*), 97
cretacea, 26
crispata, 79
divaricata, 69
(*echinata*), 82
engadinensis, 11
erecta, 35
erythranthera, 90
escarena, 96
(*europaea*), 97
fastigiata, 29*a*
fastigiata glauca, 29*b*
(*frieseana*), 2
funebris, 24
genevensis Bauhin, 96
genevensis Beissner, 47
genuina, 96
gibba Christ, 82
(*gibba* Heer), 82
gibberosa, 56
(*glauca*), 45
globosa, 43*a*
globosa nana, 43*c*
globosa viridis, 43*b*
haguenensis, 10
hamata, 84
hercynica, 9
horizontalis, 27
(*humilis*), 98
(*hybrida*), 96
intermedia, 36
jacutensis, 22
katakeimenos, 51
kienitzii, 53
(*kochiana*), 16
laevigata, 58
lapponica, 2
latifolia, 68
leucosperma, 93
macrocarpa, 86
(*maritima*), 98
melanosperma, 92
microphylla, 63
mongolica, 25
monophylla, 80
(*montana* Matthiolus), 62
montana Sang, 62
(*montana* Wahlenb.), 98
monticola, 91
(*mughus*), 94
nana Carrière, 42
(*nana* Pall), 42, 50
nevadensis, 15
nivea, 74
pannonica, 14
parvifolia, 64

pendula, 38
(*persica*), 68
phoenoperma, 95
plana Christ, 81
(*plana* Heer), 81
plicata, 37
(*pontica*), 97
pumila, 45
(*pumilio*), 45
pygmaea, 44
pyramidalis, 31*a*
pyramidalis compacta, 31*c*
pyramidalis glauca, 31*b*
reflexa, 83
rigensis, 4
rotundata, 98
(*rubra* Borkh.), 59
(*rubra* Endl.), 59
(*rubra* Grigor), 59
rubra hort., 59
rubra Senilis, 61
(*rubriflora*), 88
saxatilis, 46
scariosa, 87
scotica Schott, 1
scotica Willdenow, 1
seitzii, 52
septentrionalis, 3
sibirica, 21
sigillata, 57
(*sphagnicola*), 97
spiralis, 78
subillyricum, 13
submontana, 97
superrhenana, 7
(*tabulaeformis*), 97
tortuosa Büttner, 41
tortuosa Don, 77
turfosa, 50
typica, 96
(*ulignosa*), 98
umbraculifera, 48
uncinata, 85
uralensis, 20
variegata, 75
viminalis, 97
vindelica, 8
virgata, 39
(*viridis compacta* Hornibrook), 73
viridis compacta hort., 73
(*volkmanni*), 83
vulgaris Clusius, 96
vulgaris Don, 96
watereri, 33

LITERATURE REFERENCES

Anonymous (1941): 'Kottejuka pa tall.' *Skogsägaren*. xvii (1), 19.

—— (1942): 'Kotterekord från Blekinge.' Ibid. xviii (2), 36.

Arnborg, T. (1941): 'Busktallen. En inventering.' *Skogen*. xxviii. 174.

—— (1946*a*): 'Pinus silvestris *f.* condensata-*kvasttallen*.' *Svenska Skogsvården. Tidskr.* xliv (4), 329.

—— (1946*b*): 'Kvasttallen———en marklig tallras.' *Tidskr. Husball. Skogsvstyr. Gavl.* iii.

Bailey, L. H. (1933): *Cultivated Conifers of North America*. New York.

Baldwin, H. I. (1933): 'The importance of the origin of forest seed.' *Emp. For. J.* xii. 198.

Bean, W. J. (1951): *Trees and Shrubs Hardy in the British Isles*. London.

Beissner, L. (1891, 1909, 1930): *Handbuch der Nadelholzkunde*, 1st, 2nd, and 3rd (Fitschen, J.) editions. Berlin.

—— (1896): 'Neues und Interessantes auf dem Gebiete der Nadelholzer.' *Mitt. deutsch. dendrol. Ges.* v. 199.

—— (1898*a*): 'Neues und Interessantes über Coniferen.' Ibid. vii. 365.

—— (1898*b*): 'Reiseerinnerungen.' Ibid. vii. 416.

—— (1899): 'Interessantes über Coniferen.' Ibid. viii. 106.

—— (1901): 'Mitteilungen über Coniferen.' Ibid. x. 334.

—— (1902): 'Mitteilungen über Coniferen.' Ibid. 449.

—— (1906): 'Mitteilungen über Coniferen.' Ibid. xv. 82.

—— (1911): *Mitt. deutsch. dendrol. Ges.* xx. 348.

Black, M. (1957): 'Variations in *Pinus contorta* Douglas in Relation to Silviculture.' Unpublished thesis. University of Aberdeen.

Büttner, G. (1897): 'Die Drehkiefer.' *Mitt. deutsch. dendrol. Ges.* vi. 334.

Butts, D., and Buchholz, J. J. (1940): 'Cotyledon Numbers in Conifers.' *Trans. Illin. Acad. Sci.* xxxiii (2), 58.

Carlisle, A. (1954): 'The Morphological and Silvicultural Variations of the Native Scots Pine (*P. silvestris* L.) of Scotland.' Unpublished thesis. University of Aberdeen.

Carrière, —. (1851–1867): *Traité générale des Conifères*. 1st and new editions. Paris.

Caspary, R. (1866): *Schrift. phys.-ökon. Ges. Königb.* vii. 49.

—— (1882–3): Ibid. xxiii, 43 and 209.

Chatin, A. (1865): 'Le pin de Riga.' *Bull. Soc. imper. zoolog. d'Acclimat., Paris*, 2nd series, ii. 96.

Christ, H. (1864): 'Beiträge zur Kenntnis europäischer *Pinus- Arten*.' *Flora, oder (allegemeine) botanische Zeitung*. xlvii. 145.
—— (1865): 'Die Formenkreise der europäischen *Pinus- Arten*.' *Bot. Z.* In Caspary, R. (1882–3), *loc. cit.*
—— (1883, 1907): *Flore de la Suisse*. Basel, Lyon, and Geneva.
Conifers in Cultivation (1932): *Report of the 1932 Conifer Conference*, edited by Chittenden, F. J. London.
Correvon, H. (1906): *Nos arbres*. Geneva and Paris.
Croux, —. (1889): *Revue horticulture*, 393.
Czoppelt, H. (1938): 'The Natural Distribution of Scots Pine in the Forest of Brosteni.' *Rev. Pădurilor*. l. 765.
Dallimore, W., and Jackson, A. B. (1948, 1954): *Handbook of* Coniferae, 3rd and 4th editions. London.
Degelius, G. (1943): 'Tall med försenad klorofyllbildning.' *Skogen*. xxx. 79.
Dengler, A. (1938): 'Über Platten- und Schuppen-borke bei den Kiefer.' *Z. Forst.- u. Jagdw.* lxx. 1 and 89.
—— (1944); *Waldbau*, 4th edition. Berlin.
Elwes, H. J. and Henry, A. (1908): *The Trees of Great Britain and Ireland*. Edinburgh.
Fintelmann, H. (1881): *Bolle. Deutscher Garten*. Also in Caspary, R. (1882–3), *loc. cit.*
François, L. (1947): 'Le Pin sylvestre de race noble de Saint-Die des Vosges.' *Rev. Eaux et For.* lviii (5–9), 265.
Fries, T. M. (1890): 'Strödda bidrag till kannedom om Skandinaviens barrtrad.' *Bot. Notiser*.
Galpern, G. D. (1949): 'O lesnoy sosne v SSSR.' *Priroda Moskva* xxxviii (5), 51.
Gams, H. (1930): 'Über Relikt und das Dolomit. *Veröff. geolog.' Inst. Rub.* 6.
Gilchrist, W. (1871): 'Report on Scots Fir (*P. silvestris*): its Cultivation and Varieties.' *Trans. R. Scot. arbor. Soc.* vi. 304.
Gordon, G. (1858, 1880): *The* Pinetum, 2nd and 3rd editions. London.
Grozdov, B. V. (1945): 'O bryanskoy botanicheskoy "anomalii".' *Bot. Z.* (*Bot. Zh. S.S.S.R.*) xxx. 178.
Gulisašvili, V. Z. (1951): 'Distribution of Forest Forming Coniferous Species in Transcaucasia and their Interrelation.' Ibid. xxxvi. (3), 277.
Heer, O. 1862): 'Section der Botanik and Zoologie, I. Die Arten und Abarten.' *Verh. schweiz. Naturf. Ges. Luzern*. 177.
Hejtmánek, J. (1953): 'Příspěvek k otázce proměnlivosti borky u borovice lesní.' *Preslia*. xxv (1), 75.
Holmerz, C. G., and Ortenblad, T. (1888): *K. svenska VetenskAkad. Handl.* xiii (3), 11. Also in Sylven, N. (1916), *loc. cit.*
Hooper, J. (1868): *Book of Evergreens*. New York.
Hornibrook, M. (1923, 1938): *Dwarf and Slow Growing Conifers*, 1st and 2nd editions. London.
Kihlman, —. ( ): In Beissner, L. (1906), *loc. cit.*
Kirchner, O., Loew, E., and Schröter, C. (1908): *Lebensgeschichte der Blutenpflanzen Mitteleuropas*. Stuttgart.
Komarov, V. L. (1934): *Flora U.R.S.S.* Leningrad.
Kruberg, J. K. (1937): 'About the Geographical Distribution of *Pinus silvestris* in the Asiatic Part of the U.S.S.R.' *Sci. mem. Herz. St. ped. Inst. and St. Inst. sci. Pedag. Leningrad*. iv (2), 241.
Lawrence, G. H. M. (1951): *Taxonomy of Vascular Plants*. New York.
Ledebour, C. F. (1833): *Flora Altaica*, iv.
Lindquist, B. (1935): 'Studier over skogligt betydelsefulla svenska tallraser, No. 1.' *Norrlands Skogsvförb Tidskr*. i. 1.
Loudon, J. C. (1838): *Arboretum et Fruticitum Britannicum*. London.
—— (1855): *Encyclopaedia of Plants*. London.
—— (1883): *Trees and Shrubs of Great Britain*. London.
Ludbrook, W. V. (1937): *Needle Fusion of Species of* Pinus *in Southern New South Wales*. Commonwealth of Australia, C.S.I.R. Pamphlet 72; Prog. Rep. 1933–6 (Melbourne).
Mágocsy-Dietz, S. (1881): 'A vörös virágú erdei fenyő.' *Erdészlap*. xx. 349.

Mayr, H. (1906): *Fremdländische Wald- und Parkbäume*. Berlin.
Mouillefert, P. (1892–8): *Traité des arbres et arbrisseaux*. Paris.
Münch, E. (1924): 'Beiträge zur Kenntnis der Kiefernrassen Deutschlands, No. I.' *Allg. Forst- u. Jagdztg.* c. 540.
Murray, J. M. (1920): 'Variation in Scots Pine.' *Trans. R. Scot. arb. Soc.* xxxiv (1), 87.
Neger, F. W. (1913): 'Die nordische oder Lapplandkiefer (*P. silvestris L.* var *lapponica* Fr.).' *Thairandter Forstl. Jahrbuch.* 101.
Nordmark, O. (1950): 'Om talltypens variation i Sydsverge.' *Svenska Skogsvfören. Tidskr.* xlviii (4), 406.
Omanović, S. (1937): 'Zlatni bor.' *Šumarski List.* lxi. 17.
Ouden, P. D. den (1949): *Coniferen, Ephedra, Ginkgo*. Wageningen.
Pardé, L. (1937): *Les Conifères*. Paris.
Rehder, A. (1940): *Manual of Cultivated Trees and Shrubs Hardy in North America*. New York.
Rol, R., Pourtet, J., and Turpin, P. (1954): 'Catalogue des espèces cultivées dans l'arboretum des Barres.' *Ann. l'École Nationale des Eaux et Forets.* ix. (1), 186, 2nd edition.
Rosenbohm, —. (1882): *Schrift. phys.-ökon. Ges. Königb.* xxiii. 58.
Rubner, K. (1934, 1953): *Die pflanzengeographischen-ökonomischen Grundlagen des Waldbaus*. Neudamm and Berlin.
Sanio, —. (1871): *Ind. sem. hort. Serol.* viii.
Schelle, E. (1920): 'Mitteilungen über Koniferen.' *Mitt. deutsch. dendrol. Ges.* xxix. 37.
Schenk, E. (1925): *Mitt. deutsch. dendrol. Ges.* xxxv. 334.
Schott, P. K. (1907): *Rassen der gemeinen Kiefer*. Pinus silvestris *L. Forstwiss. Cbl.* 262.
Schotte, G. (1905): *Mitt. forstl. Versuchsanstalt Schwed.* ii.
Schreiner, E. J. (1956): 'Report on a Reconnaissance of *Pinus silvestris* in Spain.' *Proc. 3rd N.E. Forest Tree Improv. Confer., Cornell Univ., Ithaca, New York. August 30–31, 1955.*
Schröter, —. (1895): *Arch. sc. phys. nat.* xxxiv. 70.
Schwerin, F. (1896): *Mitt. deutsch. dendrol. Ges.* v. 225.
—— (1906): 'Notizen über Coniferen.' *Mitt. deutsch. dendrol. Ges.* xv. 191.
—— (1911): 'Neue Gehölze. *Pinus silvestris laevigata*.' Ibid. xx. 423.
Seitz, D. (1926): 'Neue Gehölze—die Plattenkiefer und die Schuppenkiefer.' Ibid. xxxvii. 348.
—— (1927): 'Kleine Mitteilungen.' Ibid. xxxviii. 384.
—— (1929–38): 'Unsere Edelkiefern'. Nos. I to VI. *Mitt. deutsch. dendrol. Ges.* (1929), xli. 150; (1930), xlii. 56; (1931), xliii. 364; (1933), xlv. 101; (1936), xlviii. 146; (1938), li. 67.
Seitz, W. (1927): *Edelrassen des Waldes*, No. IV. *Unsere Urkiefern*. Berlin.
Selby, J. G. (1842): *A History of British Forest Trees*. London.
Senilis, J. N. (1866): *Pinaceae*. London.
Sivers, von (1903): *Die forstlichen Verhältnisse der saltischen Provinzen*. Riga.
Slavin, A. D. (1932); In *Conifers in Cultivation* (1932), *loc. cit.*
Sokolowski, M. (1937): 'Sosna reliktowa *Pinus silvestris* f. *bamata* na Kaukazie.' *Rocznn. Nauk rol.* xli. 213.
Sorauer, P. (1909): *Handbuch der Pflanzenkrankheiten*, 3rd edition. Berlin.
Stecki, K. (1937): 'Nowa forma sosny pospolitej.' *Rocznn. Nauk. rol.* xli. 217.
Steven, C. (1838): 'Pines Found in the Taurian Caucasus.' *Bull. Soc. Imp. Natur. Mosc.* Also in *London J. C.* (1839); *Magazine of Gardening*, N.S. v (5), 229.
Sukatchev, V. N. (1938): *Dendrology and the Basis of Geobotany*. Leningrad.
Sylven, N. (1910): *Medd. Skogsforskn. Inst.* Stockh. vii. 175.
—— (1916): 'Den nordsvenska tallen.' *Medd. f. stat. Skogsförsök.* xiii. 9.
Syreitschikow, —. (1906): *Illustr. Fl. des Gouv. Moskau.* Also in Beissner, L. (1930), *loc. cit.*
Tscherning, —. (1899): 'Über *Pinus silvestris* L. f. *baenitzii* in von Karlsbad in Bohemia.' *Deutsche bot. Monatsschr.* xvii. 136.
Turrill, W. B. (1948): *British Plant Life*. London.
Vazquez, E. G. (1947): *Silvicultura*. 2nd edition. Dossat, S. A.
Veitch, J. (1900): *Manual of Conifers*, 2nd edition. Edited by Kent, A. H. Chelsea.
Webster, A. D. (1896): 'The One-leaved Scotch Pine.' *Gardeners' Chronicle*, 3rd series, xix. 104.

Willkomm, M. (1887): *Forstliche Flora von Deutschland und Oesterreich*. Leipzig.
Woerlein, —. (1893): *Ber. Bayr. Bot. Ges.* iii. 181.
Young, H. E. (1935): 'Fused Needle of Species of Pine.' *Queensland Agric. J.* xliv. 286.
—— (1940): 'Fused Needle Disease and its Relation to the Nutrition of *Pinus*.' *Queensland For. Serv. Bull.* xiii. 1.

Footnote

Since this paper was written, the author has seen a copy of a work by the Czech, P. Svoboda, *Lesní Dřeviny a Jejich Porosty*, Prague, 1953. In this book the major tree species are described in detail, and much of the nomenclature is completely new. Svoboda considers Scots pine (*P. silvestris* L.) throughout its geographical range and gives a separate botanical term for the Scots pine of each relatively small region. Thus he gives *P. silvestris alpina, baltica, baschirica, carpatica, fennica, ibirica, kasachstanica, norvegica, obensis, polonica, pyreneica, rhodopaea, romanica, rossica, sarmatica, scythica, stepposa, ucrainica*, and others, most of which are self-explanatory, together with distribution maps. There is also a mention of morphological forms such as f. *corticans* Dom., a type with rough bark reaching high up the stem: f. *kaludinensis* Sukač., with large cones; and three habit types f. *spicata, paniculata*, and *umbellata*. None of these terms is in general use, except perhaps in some of the Russian literature.

REVIEWS

Forest Soils: Their Properties in Relation to Silviculture. By S. A. WILDE. The Ronald Press Company, 15 East 26th Street, New York 10, 1958. Pp. 537. Illustrated. Price $8.50.

Review by H. M. STEVEN

PROFESSOR WILDE'S earlier book, *Forest Soils and Forest Growth*, published in 1946, was reviewed in some detail by this reviewer in *Forestry*, XX. The present book is more than a new edition, but it has the same compass and distinctive characteristics. It is divided into two parts, Part I entitled 'Soil as a Medium for Tree Growth', and Part II, 'Soil Science and Silviculture'. Like the earlier volume, this book ranges over a wide field. The different chapters in Part I deal with the following topics: soil-forming minerals, the weathering cycle, and the characteristics of various kinds of transported material; the organisms of forest soils, and it is of interest to note that he gives some attention to the role of tree root systems in soil formation as well as to bacteria, fungi, animals, &c.; forest humus, which is discussed in some detail, and its importance in silviculture is stressed; soil genesis with brief descriptions of the principal soil types which, as in the earlier book, he divides into two broad categories, Upland Forest Soil Groups and Hydromorphic Forest Soils, the latter including gley and organic soils; physical and chemical properties of soil; and a concluding chapter on the relation of forest vegetation to soils which includes brief descriptions of the link existing between soil and forest in selected forest regions in different parts of the world. There is much of interest in this part, and the last chapter will broaden the outlook of most soil scientists as well as foresters, but only those with detailed knowledge of the respective regions could comment critically on Wilde's summaries.

Part II deals more with silviculture than soils. In the earlier volume forest nurseries received considerable attention and in the present one three chapters are devoted to this subject. These cover a wide field and make available to readers in this country some at least of the current ideas in America. Wilde is clearly not happy about the effect on the soil of the use of various biocides. He also quotes a view that stimulation of the growth of seedlings by, for example, allyl alcohol leads to reduced resistance to drought. No reference is made to the intensive research carried out since the war in this country on forest nursery problems and particularly on fertilization. The remaining chapters in this part deal with forest soil survey, soils and reforestation, unproductive soils and their improvement, soils and silvicultural cuttings and soils and forest management. The last two chapters contain brief discussions on various topics from the effect of thinnings to yield regulation. The large number of subjects dealt with leads to a somewhat scrappy treatment of some of the topics.

The book is well illustrated by photographs and diagrams. The field covered is too large and diverse to make it a good textbook, but it contains much interesting material, and it can be recommended to those with some knowledge of the fields covered.

Journal of the Institute of Wood Science. Volume I, 1958. The Institute of Wood Science Ltd., 21 College Hill, London, E.C. 4. Pp. 64. 7¼ by 9¾ inches. Price 15*s*.

Review by H. G. CHAMPION and L. CHALK

WE welcome the appearance of the first number of the *Journal of the Institute of Wood Science*, dated March 1958, which has recently been received; we recommend it to

all who like to keep in touch with developments in this field. The Institute was formed in 1955 and is incorporated under the Companies Act. The publication of a journal is naturally one of the chief ways in which it can further its avowed purpose 'to advance the scientific, technical, practical and general knowledge of persons interested in the study of wood and allied subjects'. The Institute has elected Mr. Bryan Latham as President, with Mr. H. A. Cox and Professor F. W. Jane as Vice-Presidents, and it would be impossible to find a more suitable triumvirate to promote development in this field. The Editor, Mr. B. A. Jay, being Deputy Director of the Timber Development Association and in charge of their Research Laboratories at Tylers Green, is equally well qualified and well situated to carry out this additional task.

The primary object of the *Journal* will be to provide a place for the publication of original papers on all aspects of wood science. Such papers tend at present to be scattered among a number of technical journals according to the particular field concerned, and so not to be readily available to many who might be interested in them. The range of topics in this number, including papers by well-known authorities on botanical, physical, and chemical aspects, indicates the breadth of cover, whilst the papers themselves set a standard that it is hoped will be maintained. The periodicity aimed at is not mentioned, probably deliberately, though further contributions are asked for within three months of the unspecified dates of future issues: possibly the Institute will be content to start with a twice yearly publication, developing to a quarterly if an adequate flow of papers comes in. It may be noted that it is hoped that written discussion of the published papers will be possible and that shorter notes on all relevant topics will be received. Reviews, editorial notices, members' views, personal news, &c., are published separately in the Institute's Newsletter, and presumably it is not planned to include this type of matter in the *Journal*.

The first article in the new journal is very appropriately on 'Wood Science—Its Past, Present and Future' and is by F. W. Jane. After an introductory account of the early writers on wood, from Pliny to Nehemiah Grew, the author concentrates on the last 40 years or so, that is from the time of the First World War. He regards the outstanding feature of this period as being the organization and co-ordination of our knowledge of wood, which has been made possible by the organized use of trained men by the State, as at our own Forest Products Research Laboratory and at the more recent Timber Development Association. By spreading a more scientific knowledge of wood among the personnel of the timber trade, we have gone a long way to achieve a satisfactory liaison between the scientists and the distributors and users of wood, an achievement with which, it may be added, Professor Jane has himself been closely associated. It is emphasized that wood science is not solely concerned with solid wood and that some of the most exciting discoveries have been in the fields of the chemistry and physics of wood.

H. E. Dadswell contributes a stimulating article on 'Wood Structure Variations occurring during Tree Growth and their Influence on Properties'. Much interesting work has been done in recent years in Australia on the causes of the various defects of timber that originate while the tree is under the control of the forester, such as brittle heart, reaction wood, changes in fibre length and micellar pitch, and on the formation of heartwood, and no one is better qualified than Dr. Dadswell to bring this considerable body of research within a single survey. Discussion of the changes that take place with age and the various features that are characteristic of the immature wood formed in the early rings near the pith is of topical interest in relation to the utilization of thinnings from softwood plantations.

P. F. Wareing, in an article on 'The Physiology of Cambial Activity', traces the history of research on the initiation of cambial activity in the stems of trees and its dependence on the downward spread of auxins developed in the expanding buds and young leaves. In discussing

the duration of cambial activity, it is suggested that the end of diameter growth is related to the end of height growth, through a cessation of the supply of auxin, and that the differences between early and late wood are due to differences in the level of auxin reaching the cambium. The article concludes with a very brief account of the effect of external conditions on cambial activity. The article is restricted to European and North American conditions.

L. D. G. Lee contributes an article entitled 'A Non-destructive Method for measuring the Elastic Anisotropy of Wood using an Ultrasonic Pulse Technique.' Using ultrasonic equipment the velocity of propagation of elastic waves was measured in three planes for two softwoods and four hardwoods and a comparison made of Young's modulus derived from these wave velocities with theoretical values based on the assumption that wood possesses rhombic symmetry. Differences in velocities in the hardwoods and the softwoods are discussed in relation to the structure of these woods.

Most methods used to measure elasticity involve the destruction of the specimen and large numbers of specimens have to be tested to overcome accidental variation due to differences in the grain or in the size of the specimen, both of which are critical factors. The technique described of ultrasonic pulse measurements may make possible rapid determinations of variation in the orientation of the grain, such as spiral and interlocked grain, that may not be visible on the outer surfaces of sawn material and, indeed, the technique might be applicable to standing timber.

The final article is on 'The Acidity of Wood' by V. R. Gray. Fresh sawdust from 109 species of hardwood and 20 species of softwood was examined by means of a Pye miniature pH meter. Half of the species were found to be sufficiently acid to be expected to corrode iron under unfavourable conditions, although much variation occurs within a single species. Thirty-six species were sufficiently acid to be likely to give persistent trouble in contact with iron under moist conditions. The relation between acidity and iron staining was also investigated. Some relation was found between botanical grouping and both degree of acidity and staining with iron. Staining was less marked with softwoods as a class than with hardwoods. Only one specimen was appreciably alkaline—a sample of Parana pine (pH 8·8). Heartwood and sapwood showed no consistent differences. It is suggested that possible corrosion problems should be considered more frequently when designing timber structures likely to become damp.

In concluding this notice and summary we congratulate the Institute on this first issue and wish the *Journal* every success.

Guide to the use of Forestry Abstracts. Revised and enlarged edition, 1958. English–French–German–Spanish. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks. Pp. 78. Price 10*s*. post free (U.S.A. and Canada $1.40).

Review by G. D. KITCHINGMAN

FORESTRY ABSTRACTS, the abstract journal issued quarterly by the Commonwealth Forestry Bureau in Oxford, is known to all foresters for its concise summary of current literature. Its growth in size, and so in value, is shown by the following figures. The first volume which appeared in 1939 contained 1,992 items and the latest (1957) 4,848 items. The total number of items in the first 18 volumes so far completed is 55,564—a truly wonderful corpus of literary analysis.

After the Second World War *Forestry Abstracts* spread so rapidly to all countries—there are now over 1,000 subscribers—that a guide was published to help readers to use them to the best advantage. The first edition of the guide appeared in 1950, and a supplement

eighteen months later. Since then so many changes have occurred both in the literature sources and in the documentary details of the abstracts themselves that a completely revised edition was needed. This new guide is a work of reference that no forest library in the world can do without. It follows the pattern of the original guide but brings all the lists up to date. Particularly valuable to librarians is the list of abbreviated titles and publishers' addresses which forms the greater part of the work. Its appearance in 1958 coincides very nearly with the Bureau's twentieth birthday and so affords a welcome opportunity to record the work done during the first twenty years.

Most readers of *Forestry* are acquainted with *Forestry Abstracts*, but probably few realize the enormous amount of work involved in producing such a complete digest of current forest literature. The basic functions of the Bureau are three: (1) collecting literature (coverage and scrutiny); (2) classification and indexing in the card catalogue; (3) dissemination (reporting and publishing the results of its work).

Coverage and scrutiny. The mass and variety of literature to be collected and examined has increased beyond all expectation. In 1939 there were 260 periodicals to be scrutinized, but today there are no less than 578 periodicals plus 770 serials, a total of 1,348, to be examined every year. The problem of coverage is, of course, increased enormously by the language difficulty: nearly half the literature of forestry today is in a language other than English, and over thirty languages are now regularly dealt with. Since the last war the number of forest periodicals published in German has almost trebled, whilst those written in Russian and other Slav languages also show a big increase.

Classification and indexing. The Bureau is the only forest documentation centre to have created its own decimal classification system and this system has been accepted by the whole world of forestry. This Oxford system, presented to the International Union of Forest Research Organizations in 1948 and finally approved in 1953, is a very great improvement on the Flury system which had been in use since 1933. Since its publication in 1954 more than 2,600 copies have been sold, a sure indication of how much it is used. It has gained a foothold in the United States where Yale (amongst others) has adopted it. It has been translated into German, French, and Dutch; and the Spanish, Finnish, Turkish, and Greek versions are now well on the way.

After it has been classified, literature is indexed on cards which are placed in that huge card catalogue in the Imperial Forestry Institute some of us know so well. This now contains 150,000 cards, about 24,000 being added every year.

Dissemination. Fifty years ago a forester could probably digest by himself most of what was currently published. But, today, so much is published every year that he cannot possibly become aware of what is going on without the aid of an abstract journal. As a famous scientist put it recently—'the volume of scientific literature is apt to defeat its own ends by becoming overwhelming'. The old-fashioned bibliographical way—a list of titles—is not enough because the title of the article may tell the reader practically nothing of what the article is really about. It is only from an abstract or summary that he can judge whether the article is important for him and whether he need read it in full detail or not.

A further feature is the Leader, which brings together and assesses the value of all the best literature on a particular aspect of a subject, in whatever language it has been published. The compilation of these leaders is of the greatest importance today to provide the student, research worker, and all interested in the subject with a critical review of the work done to date. Their compilation must give the Editor considerable difficulty because they can only be done satisfactorily by compilers who know the subject well enough to be able to say what is good and useful reading, and what is out of date or untrustworthy. Such men are scattered all over the world and are not easily persuaded to prepare papers of this sort.

A new venture in dissemination—a centralized title service—was started in 1951. This is the dispatch, usually about five months before the publication of *Forestry Abstracts*, of a copy of the master cards made for the card catalogue index of the Imperial Forestry Institute in Oxford. This enables subscribers to get the details (and often a short abstract at the bottom of the card) of the most recently published literature. The service has steadily expanded: from one subscriber (Australia) in 1951 to 87 subscribers now, involving the dispatch of over three-quarters of a million cards every year.

Other services. In addition to its main task of publishing *Forestry Abstracts* the Bureau has taken in hand many other information services. It answers requests for selected references or definite items of literature; it undertakes translations and runs the Commonwealth scheme of translations; it is responsible for the annual national forest bibliography; it does photo-reproduction and runs short documentation courses; and, amongst other activities, is engaged on the compilation (for FAO) of a multi-linugal dictionary.

It is clear from the Director's last report that some of these auxiliary tasks cannot be done satisfactorily because there is not staff enough in the Bureau to do them. The Bureau seems a 'willing horse', constantly saddled with more jobs than it really has time for. Take the translation work for instance: only eight translations 'of no great length' could be done in the last five years. Considering the growing importance of translations in facilitating scientific communication today, one is tempted to suggest that some other forestry documentation centre, say in Canada or Australia, might relieve the Bureau of translation work and run the Commonwealth scheme. As every one knows, the requests for translations are increasing every year. And this huge task of compiling a multi-lingual dictionary—would it not be better allocated elsewhere?

The writer of this review has, during the last eleven years, probably made more use of the Bureau's services than anyone else in this country. He is lost in admiration for what it does, but at the same time he often wonders if there is not a danger that the Bureau may take on too many of these international projects before the requisite staff and money have been provided. *Forestry Abstracts* is unique in its own field, and nothing must be allowed to interfere with its full perfection.

The Effect of Afforestation on Rainfall and Run-off. By A. J. Rutter. Paper read at a meeting of the Institution of Public Health Engineers in London, February 1958 and published in *The Surveyor*, Vol. cxvii, number 3436, 1 March 1958.

Review by W. A. Cadman

THIS is an excellent summary of the work which has been done in many parts of the world on a difficult and controversial subject. The paper points out that the effect of afforestation on precipitation is negligible except in areas of low cloud where there may be some increase from fog drip. As regards run-off, an experiment at Coweeta in the Appalachian mountains in 1941, referred to by Hoover in 1944, where trees on a catchment area were felled, increased the run-off considerably. The water yield from a forest area may be between 5 per cent. and 15 per cent. less than that from adjacent areas of grass. Law, in a paper read before the British Association at Sheffield in 1956, found greater losses by use of a Lysimeter. But his experiment was confined to about 0·1 acre of Sitka spruce, which could not properly be described as constituting forest conditions.

Transpiration, interception, and evaporation are all interrelated. All are affected by solar radiation, only 40 per cent. of which is, however, related to the problem, the rest

being taken up by heating the air, reflection, and re-radiation. Estimates of transpiration losses via the leaves of a forest are very unreliable. The rate of transpiration varies with the humidity of the atmosphere and with the amount of soil water available at any given time. As available soil water is reduced, so transpiration is restricted by stomatal closure. Interception of rainfall by foliage varies from a little to as high as 50 per cent. during heavy rainfall. Open grass land may intercept 20 per cent. to 30 per cent. Against this, under forest conditions, evaporation of soil moisture is greatly reduced.

Thinning a forest increases the amount of rainfall which reaches the soil, but this gain is balanced by the losses due to increased transpiration and soil moisture evaporation. A forest of separate clumps of trees, or where very tall trees project far beyond the general canopy level, would present a greater surface for wind movement and therefore greater removal of water vapour. The difference in rooting depths between species are more significant in dry climates than where summer rain is frequent. Areas of high rainfall and sharp relief result in rapid run-off and consequential soil erosion and flooding. Lloyd, in 1953 in a contribution to a discussion on the Lynmouth flood of August 1952, has compared hydrographs from Lake Vyrnwy catchment area to show that the peak rate of discharge from the afforested Marchnant valley was less than half that from the treeless Cownwy valley, but the period of discharge was considerably prolonged.

It is a pity that Dr. Rutter has confined his article to the effects of afforestation on rainfall and run-off. These are only parts of the real problem, which is the effect upon the storage capacity of reservoirs. This aspect seems to have been ignored by the writers whom he quotes.

The water requirement of a reservoir is that the intake (that is the run-off of the catchment area) shall exceed the draw-off (i.e. commercial and domestic usage) by a safe margin. In practice, during winter or other periods of wet weather (July is often a very wet month in hill country) the intake greatly exceeds the draw-off and much water is wasted by surplus overflow. At these times the effects of afforestation are wholly beneficial, because the peak run-off of catchment areas is reduced (with consequent reduction of soil erosion and silting of the reservoirs) while the period of intake is lengthened.

During summer, or dry weather, the draw-off will exceed the intake, and the overspill of surplus water will cease. At this time of year the total run-off of the catchment area may be reduced by afforestation and *for a limited period* some effects of afforestation may not be beneficial.

Any final assessment of the benefits of afforestation of the catchment area should be based on the balance of all effects in relation to the draw-off of the reservoir—not in relation to the run-off of the catchment area only—together with the other effects of afforestation: purification of water supply, rural employment, timber production, amenity, and prevention of silting.

England's Forests. By H. L. Edlin. Faber & Faber Ltd., London, 1958. Pp. 223, with 41 photographs and 8 maps. Price 30*s.* net.

Review by W. M. McNeill

I HAVE often thought how useful it would be to have a book like this to have handy when travelling through the country. It is a good thing that one has been written and I can think of no one better able to write it than Mr. Edlin. The sub-title of the book is 'A survey of the woodlands old and new in the English and Welsh counties'. The author has drawn freely on the excellent mine of information provided by the Forestry Com-

mission Census of Woodlands, but these are reports more usually consulted by the professional forester while this book is likely to be useful and interesting to the ordinary citizen who takes an intelligent interest in his great heritage of the country scenery and landscape. But the book is much more than a popular handy edition of the official census, for Mr. Edlin draws on his interest in history, place-names, folk-lore, and literature, and combines with it his knowledge of forests to make his survey all the more interesting and intimate.

The plan of the book is a circular tour round England and Wales starting with Northumberland and finishing up with the Lake District. The purpose of the book, to quote the author's own words, is 'to paint a broad picture, bringing out the inherent character of each county's woodlands'. In a valuable and informative introduction the general historical background to the present-day distribution of our forests and woodlands is sketched, and then in subsequent chapters groups of counties are dealt with, the characteristic scenery of each outlined, and the position and composition of previous and recently formed forests described.

To supplement the narrative, outline maps are conveniently scattered through the book showing the location of the forests mentioned. These maps tempt me to make a slight criticism of an otherwise excellently produced book. Some of the place-names are in such small print that they are hard to read and the use of different lettering to indicate the old and the new forests is nowhere explained. Maps are such an essential to a book of this kind that more of these, more clearly drawn on a larger scale, would have been an improvement even if it meant sacrificing some of the fine photographs reproduced.

Mr. Edlin's knowledge of the forests of England and Wales is remarkable and he has supplied a delightfully written book that very few of us could afford to do without. It now remains to have a companion volume dealing with the forests north of the border.

The Living Forest. By H. L. Edlin. Thames & Hudson Ltd., 30 Bloomsbury Street, London W.C. 1, 1958. Pp. 310. Price 25*s.* net.

Review by John Workman

MR. EDLIN has since the last war produced a whole collection of books on trees and Forestry and everything connected with them. All have been of outstanding interest, well written, and well produced, and have probably done much to promote the ideas of forestry in Britain. Official publications and learned discourses on special subjects only reach a limited public and often are only read by the converted. To present facts, to expose falsehoods, and hold attention is an art which few writers or lecturers on technical matters possess.

The Living Forest is a curious mixture. It is not a book on forestry nor a book on strict ecology. It is rather a study of the influence of trees, commonly grown in Britain, from a sociological viewpoint. Each tree is dealt with according to its general importance, its uses, origin, and folk-lore. As Mr. Edlin says in his foreword, he has tried to outline those facts about trees and their timbers which have interested him most, in the belief that they are the points that will most appeal to others. I believe he has succeeded admirably, though details are apt to be arranged in a different order for each species. For instance, the botanical names appear anywhere in the text. This does not matter when you are reading the book, in fact it enhances the readability, but it is very trying when you want to look up some point, though, of course, it is not meant to be a textbook.

The book is divided into two parts. 'The Coming of the Natives', which deals with species supposed to have reached these islands without the aid of man. Modern research on pollen analyses are quoted and I should have liked more details on this subject. The second half deals with introduced species. Both parts include details of all trees grown on a forest scale, as well as many normally only appearing in pleasure grounds and arboreta. Shrubs of various sorts are included, on the strength of their appearance in woods.

Mr. Edlin has a passion, which I share, for the study of English place-names. In a language like English, which has evolved from several distinct origins and where local dialects are still so different, it is possible to devise several analyses for any one name. In this book we are given Gaelic, Latin, Anglo-Saxon, and Celtic origins and some of these are offered as evidence that a species is native. For instance, we are told that on linguistic grounds alone we can dismiss the theory that elm is a foreign tree. It is probably true that old place-names, like folk-songs, linger on in spite of invasions and changes of culture. It is a fascinating study and I hope Mr. Edlin will develop it.

The book is a mine of information and very accurate, but there are several details which call for comment or need enlarging perhaps in another edition. Podzolization needs a bit more definition for the layman. Scots pine and Norway spruce do reach timber size on limestone. I am sad to see the badger described as a beast of prey. With regard to oak, I wish we knew more about the causes of shake. The information on rate of growth and spring wood and summer wood is more clearly set out than I have ever seen. The continued pollarding of beeches is frowned upon, but surely it is worth trying to ensure that a few specimens of this outmoded treatment survive to warn future generations. Thorn hedges are normally only laid about every fifteen years, not every five. To ensure fruiting, both male and female plants of sea buckthorn must be planted.

These are only small points in a book which gives the history of many of our oldest and most famous trees, lists the tallest and fattest trees of each species in Britain and tells us that Highland maidens used to make a hair rinse from birch twigs!

To the readers of this learned journal, I would say that you will enjoy this as a bedside book and your wife may enjoy it even more. There are no pictures, it does not need illustrating and, though pictures might have attracted a wider market, they would inevitably have increased the price.

The Growth and Structure of Wood. By B. J. Rendle. Forest Products Research Record, No. 21, second edition. London, H.M.S.O., 1957. Pp. 20. Illustrated. Price 1*s.* 9*d.* net.

Review by C. J. Venables

THIS second edition of Mr. Rendle's excellent little pamphlet is long overdue. It deals in simple language with the classifications of timbers, the growth of a tree, the structure and properties of wood, its physical and chemical composition, and its moisture contents. It defines many technical terms and concludes with a helpful paragraph on the identification of timbers.

In so small a compass it is impossible to deal extensively with any one of these vast subjects, but the very brevity of the pamphlet has much to commend it to the busy timber merchant and the busy timber user in these days when so much literature is pouring from the press every day.

The professional forester will find the clear statements of facts fundamental to the study of the properties and processing of wood extremely useful. These clear statements will

enable the layman also to avoid many of the pitfalls of wide generalizations on the relations between the rate of growth and the strength and the working qualities of timber.

A copy of this pamphlet should be amongst the books of reference on the shelf of all 'members of the timber-using trade and professions', who will, indeed, find it to be what it sets out in the first paragraph to be—namely, 'an introduction to technical literature on timber'.

We are living in a day when it is realized that to grow the maximum volume of wood as quickly as possible is not enough, and foresters in this country are being challenged to consider the ultimate markets for which they are planting and growing trees. They are facing this challenge in all seriousness, and are turning to the timber trade and the ultimate timber-users for co-operation and assistance. In their mutual discussions it is essential that all parties should attach exactly the same meaning to the terms that they employ.

Mr. Rendle's pamphlet will have been extremely worth while if its only achievement is to enable all who are vitally interested in these discussions to understand clearly what is meant by the technical terms—without the use of which such discussions cannot be carried on.

World Forest Products Statistics, 1946–1955. A Ten-year Summary. Food and Agricultural Organization of the United Nations, Rome, 1957. Pp. 197. H.M.S.O., London, 1958. Price 15*s*.

Review by J. J. MacGregor

FAO is to be commended on the way in which, in a very short period, it has gradually built up the comprehensiveness of its forest products statistics to include, for some comparisons, about 150 separate countries. Inevitably the later years cover more information and more countries, but the ten-year summary is a useful reference book supplementing the statistics of volume available in the separate FAO yearbooks which have appeared since 1946.

The main feature is the inclusion of fifty-one tables of volume data under Removals, Production, and Exports and Imports. In some of the tables the data are absent or incomplete in varying degrees. Throughout a distinction is made between broad-leaved and coniferous products, and between total removals; industrial wood; fuelwood; sawlogs, veneer logs and logs for sleepers; pulpwood and pitprops; and other industrial wood. The analysis of production cover sawnwood, sleepers, plywood, mechanical and chemical wood-pulp, other fibre-pulp, compressed and non-compressed fibreboard, newsprint and other forms of paper, and paperboard. The Export–Import analyses follow the same pattern. In addition to the main tables there are general notes and appendixes covering technical notes, definitions of terms, converting factors and country notes. A summary entitled 'Highlights of the Ten-year Period' is supported by a series of index numbers (1953 = 100) for removals and production—mainly on a broad regional basis.

Attention is drawn to the regional pattern of production and to the main exporting and importing countries which are discussed in the report. In spite of technological developments in veneer peeling and slicing, in pulping and in resin-bonding, sawnwood remains the king of forest products. Wood-pulp manufacture has been expanded and geographically spread in association with the use of a greater variety of conifers and broad-leaved species. Although a third of the world paper production is newsprint, a significant growth of wrapping papers and use of paper-board for packaging is noted.

Regions where the growth of output in the main categories of forest products were particularly outstanding is shown clearly in a number of charts and an index number, with 1953

as 100, shows the following measure of growth for the world as a whole for the eight main industrial products:

	1946	1955		1946	1955
Sawnwood . .	70	111	Newsprint .	66	114
Plywood . . .	36	127	Other paper .	63	123
Wood-pulp . .	58	119	Paperboard .	62	117
Other fibre-pulp .	73	124	Fibreboard .	54	129

In an age of planning, estimating, and forecasting there is no need to stress the demand for up-to-date statistics. The above publication can be judged in this context as a most useful reference for surveying, in a broad way, some of the world trends and for judging comparatively the developments in individual countries. In some respects, however, it is not a complete substitute for the annual FAO yearbooks. For example, the 1957 yearbook gives measures of trend to include 1956; shows, for the main categories, such additional information as exports by destination and imports by origin and their values; total forest product balances in roundwood equivalents (i.e. removals, imports, and exports); *per caput* consumption, and land and forest areas.

In spite of some deficiencies, the foreword claims that the publication is believed to be the most complete and authoritative world-wide statistical report on forest products for the post-war period that has yet been published. In a sense, it is a history of the decade of development in world forestry—a record of the increasing contribution of forests to human welfare.

Chemicals Involved in Air Pollution and their Effects upon Vegetation. By P. W. ZIMMERMAN. Boyce Thompson Institute for Plant Research, Inc. New York. Reprinted from proceedings of conference on Atmospheric Pollution 1952 and published as a professional paper, vol. 2, no. 14, 1955. Pp. 22, with 33 references to literature. Illustrated with photographs.

Leaf Absorption of Wind-blown Salt and Leaf Scorch in Eucalyptus camaldulensis *Dehn.* By R. KARSCHON. Forest Research Station, Ilanoth, State of Israel, 1958. Pp. 25 with 38 references to literature. Illustrated with photographs.

Review by the EDITOR

BOTH these papers are of interest in the British Isles today. Both consider the uses and limitations of the visual effects of air pollution on plants in the diagnosis of cause. The first paper deals mainly with the results of research in the laboratory and their application to industrial pollution. The second paper shows how wind-blown salt can restrict choice in the introduction of tree growth in an area.

The Boyce Thompson Institute paper notes that, while the quantities of effluents around industrial areas can be determined by comparing the injury found in plants with the degree of injury induced under known experimental conditions, it is more difficult to identify the impurity itself by visual means. Smog symptoms are not always characteristic for any one chemical. Symptoms due to chemical injury sometimes resemble those resulting from disease.

To aid in identifying characteristic effects, several species of plants have been subjected at the Institute to known gases under controlled experimental conditions and under different conditions of temperature, water-supply, sulphur content of nutrients, and age of plants. The main object of the paper is to present a short review of observations arising out of the experimental work undertaken.

The paper notes for instance that varieties of a given species may vary widely in their susceptibility to a given gas. And for given gases, the effects may even be reversed. This underlines the importance of the standardization of the test objects so that results from different laboratories can be compared. The paper notes that these differences may eventually lead to a better understanding of how gases injure plants. Turgidity renders plants more susceptible to injury whereas wilting increases resistance. Relative humidity makes little difference and it is the internal condition of the plant rather than the external condition which is important. With sulphur dioxide and hydrofluoric acid, middle-aged leaves are most susceptible and young leaves least susceptible. A fact that must make visual diagnosis in the field more difficult as in the course of a summer leaves are liable to be attacked by a succession of different things.

The paper notes that there is no such thing as 'invisible injury' by gases and lists sulphur dioxide (SO_2), hydrofluoric acid (HF), chlorine, hydrogen sulphide, ammonia, growth-regulating substances, and illuminating gas as the toxic impurities most frequently met with. Photographs are given to show characteristic injury from SO_2, HF, chlorine, and mercury vapour but it is agreed that some cases of injury are not distinguishable. Moreover, with the advent of hormone-like chemicals, several new-comers have been added to the list and a final photograph shows modifications of different species of plants collected in the vicinity of an industrial plant which manufactured and packaged preparations of 2, 4-D.

By contrast with the above, Dr. Karschon in the Israel research paper was occupied with the cause of a specific form of leaf scorch and defoliation in plantations of *Eucalyptus camaldulensis* (formerly *E. rostrata*) in the wind-swept coastal plain of the State of Israel. In the introduction, he states that *E. camaldulensis* is the main species planted in the country and the main source of timber for industrial and agricultural purposes. Leaf burn is prevalent as far as 4 to 8 km. inland.

A well defined line of demarcation between the scorched tips and margins and the green part of the leaves and generally an absence of discoloration, spotting, or intervenal chlorosis showed that the cause was not lime-induced iron deficiency. Potassium deficiency was not suspected and was finally discounted after dressings of potassic fertilizer failed to depress the leaf sodium or to reduce the scorch. Quantitative chemical analysis of cleaned leaves taken from trees growing on non-saline soils was therefore undertaken to see if wind-borne salt was the cause as distinct from mere wind which could be overcome by the provision of shelter. The analysis undertaken proved this to be the case and the data collected show clear increases in sodium and chloride contents in proportion to the degree of scorch. These are shown in some detail in text-figures and in tables.

While no explanation is put forward concerning the process involved in sodium and chloride absorption by eucalypt leaves, the analysis shows high levels of absorption and low tolerance, and Karschon concludes that *E. camaldulensis* is unsuitable for commercial growing on land exposed to sea winds. He indicates that research into tolerance of other eucalypts is being undertaken.

Forestry Terminology. A Glossary of Technical Terms Used in Forestry. Third Revised Edition, 1958. Edited by Arthur B. Meyer and F. H. Eyre. Society of American Foresters, Washington D.C. 10½ inches by 7½ inches. Pp. 97. Price $3.50 postpaid.

Review by the Editor

WE quote an extract from Professor Champion's review of the first edition of *Forestry Terminology* which was published in 1944. Professor Champion's review appeared in

the *Empire Forestry Journal*, vol. xxiii, no. 2, at p. 168, and is also quoted in the introduction to the Empire Forestry Association's *British Commonwealth Forest Terminology*, Part I, 1953.

'. . . It is full time that British foresters should submit their own vocabulary to a similar detailed scrutiny and publish a terminology which will enable the American to know what the Britisher means when he talks or writes "shop", in the same way as the volume under review renders the corresponding service to them. There is no more appropriate body to undertake this task than the Empire Forestry Association . . . Further, it may be hoped that an outcome of the two publications will be a joint effort to reduce the number of terms which are used in different senses in different parts of the world, and that a more widespread knowledge of terms already in use will reduce the likelihood that such differences will arise in future.'

The publication of Part I of the *British Commonwealth Forest Terminology* in 1953 and of Part II in 1957, both under the care and supervision of the late H. R. Blandford, seem thus the direct result of the initiative taken by the Society of American Foresters, and we are delighted now to welcome the publication of this third revised edition which brings us still nearer to our common object and we may suitably quote from the preface to this edition:

'*Forest Terminology* is a source of information on those terms that foresters, working in many specialized fields, use in their daily tasks.

'In keeping with the fact that the technical language of forestry utilizes a growing, changing vocabulary, this third edition contains new terms and definitions not occurring in the previous edition. Such terms fall primarily in the fields of genetics, aerial photography and wood utilization. . . . Slight changes of wording have been made in certain definitions when it was possible, without change of meaning, to arrive at a definition mutually accepted by British and American foresters.'

In other respects the glossary follows the pattern of the first and second editions 'in the belief that such a glossary has two functions: it should reflect growth and change in the vocabulary; but it should strive also for stability'.

It must be about three years ago now that Mr. Arthur Meyer, the joint Editor, spent some time in Oxford in consultation about the glossary and when we among others had the pleasure and privilege of meeting him.

The Society of American Foresters are to be congratulated on this new edition. The book is beautifully printed and easy to use. Its value is such that every forester ought to possess one.

CORRIGENDA

Forestry, Vol. XXXI, No. 1, page 25.

Literature References. Wright and Will. Against Scott, R. O., and Ure, A. M. (1957): *Delete* 'Spectrophotometry' and *substitute* 'Photometry'. Delete, *N.Z.J. Sci. Tech. B. XXXVIII. 699–706* and substitute 'To appear in *The Analyst*'.

continued from inside front cover]

The membership is divided into four classes, the respective qualifications being as outlined below:

FELLOWS: Subjects of the British Crown fulfilling all four of the following requirements: (1) A degree or diploma in forestry, &c. (2) Five years of practical experience in forestry, &c. (3) Having been a Professional Associate for 5 years. (4) Having had a thesis or published article approved by the Council. Annual subscription £2. 2*s*. 0*d*. (Twenty-five guineas for life.)

PROFESSIONAL ASSOCIATES: Subjects of the British Crown fulfilling any one of the following requirements: (1) A degree or diploma in forestry, &c. (2) Having made important contributions to forestry, &c. (3) Considered by the Council to occupy a post normally held by a holder of a university degree in forestry. Annual subscription £1. 1*s*. 0*d*. (Sixth *et seq.* £2. 2*s*. 0*d*.)

PROFESSIONAL MEMBERS: Subjects of the British Crown resident in Great Britain, engaged whole time in forestry but not eligible for above classes. Annual subscription £1. 1*s*. 0*d*.

ORDINARY MEMBERS: Persons or corporate bodies not eligible for any of above classes. Annual subscription £2. 2*s*. 0*d*.

Fuller details of qualifications may be obtained from the Secretary.

Only Fellows are eligible for the higher offices and for most seats on the Council, but one Councillor may be a Professional Associate and one a Professional Member. Office bearers and Councillors are selected by written nomination and postal ballot. Fellows and Professional Associates have full voting rights, but Professional Members have only limited voting rights.

LIST OF OFFICE BEARERS 1957–8 AND COUNCILLORS 1957–9

President: A. P. LONG, C.B.E., B.A., Chatley, Martins End Lane, Great Missenden, Bucks.

Vice-President: PROFESSOR SIR HARRY CHAMPION, C.I.E., M.A., D.SC., Imperial Forestry Institute, Oxford.

Editor: R. W. V. PALMER, B.A., Bannerleigh, Leigh Woods, Bristol.

Business Editor: H. L. EDLIN, B.SC., Forestry Commission, 25 Savile Row, London, W.1. Tel. REGENT 0221.

Secretary and Treasurer: R. A. GALLOWAY, O.B.E., M.C., B.SC., Solicitor, 7 Albyn Place, Edinburgh, 2. Tel. CAL. 7402.

Auditor: D. L. FERGUSON, 11 Carlton Terrace, Edinburgh, 7.

Councillors: while immediate past president, W. E. HILEY; *retire in* 1958 *but eligible for re-election,* SIR HENRY BERESFORD-PEIRSE, J. A. B. MACDONALD, M. V. LAURIE, *and* C. A. CONNELL (*Fellows*), *and* J. F. MCGARVA (*Professional Associate*); *retire in* 1959 *but eligible for re-election,* W. M. MCNEILL, J. E. GARFITT, R. H. HIDE, PROFESSOR E. C. MOBBS *and* B. J. RENDLE.

the *Empire Forestry Journal*, vol. xxiii, no. 2, at p. 168, and is also quoted in the introduction to the Empire Forestry Association's *British Commonwealth Forest Terminology*, Part I, 1953.

'. . . It is full time that British foresters should submit their own vocabulary to a similar detailed scrutiny and publish a terminology which will enable the American to know what the Britisher means when he talks or writes "shop", in the same way as the volume under review renders the corresponding service to them. There is no more appropriate body to undertake this task than the Empire Forestry Association . . . Further, it may be hoped that an outcome of the two publications will be a joint effort to reduce the number of terms which are used in different senses in different parts of the world, and that a more widespread knowledge of terms already in use will reduce the likelihood that such differences will arise in future.'

The publication of Part I of the *British Commonwealth Forest Terminology* in 1953 and of Part II in 1957, both under the care and supervision of the late H. R. Blandford, seem thus the direct result of the initiative taken by the Society of American Foresters, and we are delighted now to welcome the publication of this third revised edition which brings us still nearer to our common object and we may suitably quote from the preface to this edition:

'*Forest Terminology* is a source of information on those terms that foresters, working in many specialized fields, use in their daily tasks.

'In keeping with the fact that the technical language of forestry utilizes a growing, changing vocabulary, this third edition contains new terms and definitions not occurring in the previous edition. Such terms fall primarily in the fields of genetics, aerial photography and wood utilization. . . . Slight changes of wording have been made in certain definitions when it was possible, without change of meaning, to arrive at a definition mutually accepted by British and American foresters.'

In other respects the glossary follows the pattern of the first and second editions 'in the belief that such a glossary has two functions: it should reflect growth and change in the vocabulary; but it should strive also for stability'.

It must be about three years ago now that Mr. Arthur Meyer, the joint Editor, spent some time in Oxford in consultation about the glossary and when we among others had the pleasure and privilege of meeting him.

The Society of American Foresters are to be congratulated on this new edition. The book is beautifully printed and easy to use. Its value is such that every forester ought to possess one.

CORRIGENDA

Forestry, Vol. XXXI, No. 1, page 25.

Literature References. Wright and Will. Against Scott, R. O., and Ure, A. M. (1957): *Delete* 'Spectrophotometry' and *substitute* 'Photometry'. Delete, *N.Z.J. Sci. Tech. B. XXXVIII. 699–706* and substitute 'To appear in *The Analyst*'.

continued from inside front cover]

The membership is divided into four classes, the respective qualifications being as outlined below:

FELLOWS: Subjects of the British Crown fulfilling all four of the following requirements: (1) A degree or diploma in forestry, &c. (2) Five years of practical experience in forestry, &c. (3) Having been a Professional Associate for 5 years. (4) Having had a thesis or published article approved by the Council. Annual subscription £2. 2*s*. 0*d*. (Twenty-five guineas for life.)

PROFESSIONAL ASSOCIATES: Subjects of the British Crown fulfilling any one of the following requirements: (1) A degree or diploma in forestry, &c. (2) Having made important contributions to forestry, &c. (3) Considered by the Council to occupy a post normally held by a holder of a university degree in forestry. Annual subscription £1. 1*s*. 0*d*. (Sixth *et seq*. £2. 2*s*. 0*d*.)

PROFESSIONAL MEMBERS: Subjects of the British Crown resident in Great Britain, engaged whole time in forestry but not eligible for above classes. Annual subscription £1. 1*s*. 0*d*.

ORDINARY MEMBERS: Persons or corporate bodies not eligible for any of above classes. Annual subscription £2. 2*s*. 0*d*.

Fuller details of qualifications may be obtained from the Secretary.

Only Fellows are eligible for the higher offices and for most seats on the Council, but one Councillor may be a Professional Associate and one a Professional Member. Office bearers and Councillors are selected by written nomination and postal ballot. Fellows and Professional Associates have full voting rights, but Professional Members have only limited voting rights.

LIST OF OFFICE BEARERS 1957–8 AND COUNCILLORS 1957–9

President: A. P. LONG, C.B.E., B.A., Chatley, Martins End Lane, Great Missenden, Bucks.

Vice-President: PROFESSOR SIR HARRY CHAMPION, C.I.E., M.A., D.SC., Imperial Forestry Institute, Oxford.

Editor: R. W. V. PALMER, B.A., Bannerleigh, Leigh Woods, Bristol.

Business Editor: H. L. EDLIN, B.SC., Forestry Commission, 25 Savile Row, London, W.1. Tel. REGENT 0221.

Secretary and Treasurer: R. A. GALLOWAY, O.B.E., M.C., B.SC., Solicitor, 7 Albyn Place, Edinburgh, 2. Tel. CAL. 7402.

Auditor: D. L. FERGUSON, 11 Carlton Terrace, Edinburgh, 7.

Councillors: while immediate past president, W. E. HILEY; *retire in* 1958 *but eligible for re-election,* SIR HENRY BERESFORD-PEIRSE, J. A. B. MACDONALD, M. V. LAURIE, *and* C. A. CONNELL (*Fellows*), *and* J. F. MCGARVA (*Professional Associate*); *retire in* 1959 *but eligible for re-election,* W. M. MCNEILL, J. E. GARFITT, R. H. HIDE, PROFESSOR E. C. MOBBS *and* B. J. RENDLE.

CONTENTS

The effect of rate of growth (ring width) on the density of softwoods (*with Plate XI*). By B. J. RENDLE and E. W. J. PHILLIPS. 113
Tree-crown deformation as an index of exposure intensity. By DAVID THOMAS . . 121
Forestry policy for the United Kingdom. *The end of an epoch* 131
Studies on *Ulmus*. II. The village elms of southern Cambridgeshire. By R. H. RICHENS 132
Methods of light intensity measurement in forest stands. I. Instrumentation. By R. D. CONNOR 147
Methods of light intensity measurement in forest stands. II. The use of light measurement instruments in the field (*with Plates XII and XIII*). By W. A. FAIRBAIRN 155
The storage of acorns in water. By EUSTACE W. JONES 163
Moisture and temperature conditions in afforested areas in Aberdeenshire. By J. R. H. COUTTS 167
The first international symposium on tree physiology. By S. D. RICHARDSON . . 177
Oak. By N. WYLIE 184
Scientific and Industrial Research. *Reconsideration of Main Tasks for the Department* 192
The Midland Wood Society conference, 1958. Growing quality timber . . 193
Northerwood conference, 1–4 May 1958. The management of coniferous crops. Summary by A. J. GRAYSON 194
National Diploma in forestry 201
Annual Excursion of the Société Royale Forestière de Belgique (M. J. P.) . . 202
A guide to the named variants of Scots pine (*Pinus silvestris* Linnaeus). By A. CARLISLE 203

REVIEWS

Forest soils: their properties in relation to silviculture (S. A. WILDE). By H. M. STEVEN 225
Journal of the Institute of Wood Science. Volume I, 1958. By H. G. CHAMPION and L. CHALK 225
Guide to the use of *Forestry Abstracts*. By G. D. KITCHINGMAN 227
The effect of afforestation on rainfall and run-off (A. J. RUTTER). By W. A. CADMAN 229
England's forests (H. L. EDLIN). By W. M. MCNEILL 230
The living forest (H. L. EDLIN). By JOHN WORKMAN 231
The growth and structure of wood (B. J. RENDLE). By C. J. VENABLES 232
World forest products statistics, 1946–55. A ten-year summary (FAO). By J. J. MACGREGOR 233
Chemicals involved in air pollution and their effects upon vegetation (P. W. ZIMMERMAN) *and* Leaf absorption of wind-blown salt and leaf scorch in *Eucalyptus camaldulensis* (R. KARSCHON). By the Editor 234
Forest Terminology. A glossary of technical terms used in forestry (ARTHUR B. MEYER and F. H. EYRE). By the Editor 235

CORRIGENDA

Forestry, Vol. XXXI, No. 1, page 25 236

Printed in Great Britain at the University Press, Oxford, by Vivian Ridler, Printer to the University